

ND-A183 984

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87

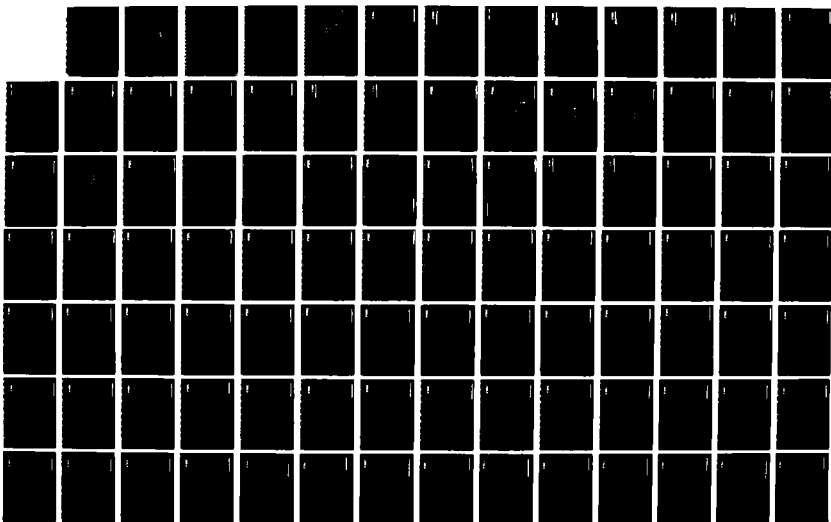
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FMC-E-3841-VOL-8-PT-2 DAAR21-86-C-8847

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MICROCOPY RESOLUTION TEST CHART

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Lightweight Towed Howitzer Demonstrator

Final Report

Volume B

Technical Presentations - Part II

April 1987

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AD-A183 984

Contract Number DAAA21-86-C-0047

FMC CORPORATION
Northern Ordnance Division
4800 East River Road
Minneapolis, Minnesota 55421

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
55mm towed gun howitzer, advanced weapons, composite cradle, composite hydraulic actuators, composite trails, field artillery weapon, firing stability analysis, howitzers, hydraulic control valves with force feedback, hydraulic joystick control of gun direction, hydraulic inertial rammer, hydraulic opening breech, hydraulic primer autoloader, lightweight towed howitzer demonstrator (LTHD) load out of battery howitzer, mortar howitzer, recoil energy recovery, recoil mechanism, using metal matrix composites, titanium muzzle brake, titanium platform, titanium spade, titanium walking beams, thermal stability, towing stability analysis, unconventional weapons, and weight reduction of artillery.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
<p>The LTHD (Lightweight Towed Howitzer Demonstrator) was to be a 9,000 lb equivalent to the M198, transportable via Blackhawk helicopter, with reduced emplacement time using fewer personnel. The FMC design achieved weight reduction via a mortar-like configuration, composites structure, and hydraulic actuators. Recovery of power from the recoil system, in turn, facilitated crew reduction via hydraulic emplacement, four-way joystick tube lay, and power ramming. FMC completed Concept Development (Ph I) and two-thirds of Detailed Design (Ph II) prior to funds running out. <i>Key words:</i></p>		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Vol/Sec	Description
B	Technical Presentations
B/050	Table of Contents
B/100	04 Jun 85 (Proposal)
B/200	25 Nov 85 (BAFO response)
B/300	04 Mar 86 (Ph 1)
B/400	04 Jun 86 (Ph 1)
B/500	01 Oct 86 (Ph 2)
B/600	29 Oct 86 (Ph 2)
B/700	15 Jan 87 (Ph 2)
B/800	19 Feb 87 (ARDEC Visit to FMC)
B/900	04 Mar 87 (Ph 2)



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Justification	
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Distribution/	
Availability Codes	
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**TECHNICAL PRESENTATION
PHASE II**



SYSTEM ENGINEERING POINTS OF CONTACT

SYSTEM ENGINEER	ERROL QUICK	(612) 572-6001
SAFETY	TOM HILLSTROM	" 572-6024
RAM	MIKE JANSSEN	" 572-7616
PA	FLOYD MANSON	" 572-6017
HUMAN FACTORS	ROBERT SCHMIDT	" 572-6344
TEST	DAVE FLIPPO	" 571-9201 x 2591
QUALITY ASSURANCE	LYMAN MALBERG	" 572-6491

LTHD
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TRADE STUDY
LOAD-IN BATTERY VS LOAD-OUT OF BATTERY

PURPOSE: TO EVALUATE THE LTHD CONCEPTS OF LOADING IN-BATTERY VS
LOADING OUT OF BATTERY

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OUT OF BATTERY VS MODIFIED SYSTEM

[illegible]

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TRADE STUDY

LOAD-IN BATTERY VS LOAD-OUT OF BATTERY SUMMARY OF ADVANTAGES/DISADVANTAGES

LOAD-OUT OF BATTERY

ADVANTAGES:

- o BETTER VISIBILITY
- o HAND LOAD PROPELLANT
- o MANUAL PRIMER INSERTION
- o WEIGHT ADDS TO STABILITY

DISADVANTAGES:

- o COMPLEX RECOIL SYSTEM (MORE WEIGHT)
- o INSTABILITY IN EVENT OF COOK-OFF IS SEVERE
- o MISFIRE PROCEDURES - DIFFICULT AT HIGH ELEVATIONS
- o MAXIMUM FIRING RATE MAY NOT BE OBTAINED
- o RELIABILITY/MAINTAINABILITY DEGRADED
- o BREECH ACCESS VERY INCONVENIENT TO CREW

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TRADE STUDY

LOAD-IN BATTERY VS LOAD-OUT OF BATTERY SUMMARY OF ADVANTAGES/DISADVANTAGES

LOAD-IN BATTERY

ADVANTAGES:

- 0 GOOD FIRING STABILITY
- 0 SIMPLE RECOIL SYSTEM
- 0 LOW BLAST OVERPRESSURE
- 0 EASE OF FIRING OPERATIONS
- 0 FIRING CYCLE TIME

DISADVANTAGES:

- 0 VISIBILITY OF OPERATIONS
- 0 POWER RAMMING OF PROPELLANT
- 0 REQUIRE PRIMER AUTOLOADER
- 0 EXCESSIVE HYDRAULICS/CONTROLS

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TRADE STUDY
SUMMARY OF CONCERNS
(AND ACTIONS TAKEN TO CORRECT THE RISKS)

CONCERNS OF OPTIONS

A & B

1. POWER RAMMING OF PROPELLANT

2. VISIBILITY OF OPERATION

3. PRIMER AUTOLOADER

4. SAFETY: COOK-OFF WHILE OUT OF
BATTERY WILL DESTROY WEAPON
SYSTEM

SOLUTIONS INCORPORATED INTO AN

OPTION C

1. MANUAL LOADING OF PROPELLANT
BY CREWMEMBER

2. CREWMEMBER IS LOCATED ADJACENT TO
BREECH ASSEMBLY

SLIDE ASSEMBLY MODIFICATION TO
PERMIT GREATER VISIBILITY

3. BACK UP MANUAL LOADING OF PRIMER
IS AN AVAILABLE OPTION

4. PROPELLANT IS LOADED 3 FEET
FROM FULL IN BATTERY POSITION.
THIS ALLOWS 5.5 FEET OF RECOIL
TO ABSORB THE COOK-OFF

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TRADE STUDY
SUMMARY OF CONCERNS (CONTINUED)
(AND ACTIONS TAKEN TO CORRECT THE RISKS)

CONCERNS OF OPTIONS

A & B

5. BORE INSPECTION AND BORE
SWABBING IS DIFFICULT

6. VARIABLE RECOIL SYSTEM

7. EXCESSIVE HYDRAULICS AND CONTROLS

SOLUTIONS INCORPORATED INTO AN

OPTION C

5. MANUALLY PERFORMED BY CREWMEMBER
LOCATED ADJACENT TO THE BREECH

6. NO LONGER REQUIRED

7. MANUAL LOADING OF PROPELLANT
ELIMINATES SOME OF THE
HYDRAULICS IN THE RAMMER
ASSEMBLY

FLICK RAMMER FURTHER DECREASES
THE HYDRAULICS REQUIRED

8. RATE OF FIRE

8. FLICK RAMMER INCREASES THE SPEED
OF THE LOADING OPERATION

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TRADE STUDY - DOLLY VS FIXED WHEELS

PURPOSE: TO EVALUATE A SEPARATE DOLLY CONFIGURED SYSTEM
VS A FIXED WHEEL SYSTEM

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TRADE STUDY: DOLLY VS FIXED WHEELS

SUMMARY OF ADVANTAGES/DISADVANTAGES

DOLLY CONCEPT

ADVANTAGES:

- o BEST TOWING STABILITY
- o DEVELOPMENT COST LESS
- o SIMPLE DESIGN
- o EMPLACEMENT IS SIMPLE
- o MOST RELIABLE
- o COMPATIBLE WITH EXISTING WEAPON DESIGN
- o PROVIDES AIRLIFT FLEXIBILITY

DISADVANTAGES:

- o WEAPON DISPLACEMENT DIFFICULT
- o SPEED SHIFTING (SEPARATE PIVOT STAND REQUIRED)
- o FIRING STABILITY IS NOT INCREASED
- o SAFETY/HUMAN FACTORS - DIFFICULT TO MOVE/POSITION DOLLY
- o LEAST SURVIVABLE
- o HARDEST TO FABRICATE AND PRODUCE

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TRADE STUDY: DOLLY VS FIXED WHEELS
SUMMARY OF ADVANTAGES/DISADVANTAGES

2 WHEEL CONCEPT

ADVANTAGES:

- o LIGHTEST IN WEIGHT
- o ADDS TO FIRING STABILITY

DISADVANTAGES:

- o POOR TOWING STABILITY
- o TONGUE WT REQUIRES A TRAILER JACK
- o DEPARTURE ANGLE IS LESS
- o DEVELOPMENT COSTS'
- o MODIFIES EXISTING WEAPON DESIGN
- o ADDS COMPLEXITY TO TRAILS

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TRADE STUDY: DOLLY VS FIXED WHEELS
SUMMARY OF ADVANTAGES/DISADVANTAGES

4 WHEEL CONCEPT

ADVANTAGES:

- o GOOD TOWING STABILITY
- o BEST DISPLACEMENT CONCEPT
- o BEST FIRING STABILITY
- o BEST UNCOUPLE/CUPLE OPERATIONS
- o MAY ELIMINATE SPADE REMOVABLE CYLINDERS
- o BETTER SURVIVABILITY

DISADVANTAGES:

- o INCREASED WEIGHT
- o MOST COMPLEX DESIGN
- o MODIFIES EXISTING WEAPON DESIGN
- o ADDS COMPLEXITY TO TRAILS

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TRADE STUDY - DOLLY VS FIXED WHEELS

CONCLUSION: INCORPORATE THE 4 WHEELS (IN THE TRAILS) CONCEPT
INTO THE LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

RISK AREAS OF CONCERN

POTENTIAL SOLUTION/ALTERNATE
COURSES OF ACTION

RISKS

MATERIALS AREA

1. COMPOSITE MATERIAL (M - H)
2. TITANIUM USED IN GIMBAL/
MUZZLE BRAKE (M)

1. TESTING/QUALITY CONTROL/
SAMPLES/MODELING
2. USED MODIFIED STEEL MUZZLE
BRAKE WITH ATTACHED LUNETTE
AND A STEEL/COMPOSITE INSERT
IN THE GIMBAL

PERFORMANCE AREA

3. ENERGY RECOVERY SYSTEM (M)
4. PRIMER AUTOLOADER (M - H)
5. FLICK RAMMER (M)
6. SPADE EMPLACEMENT/DISPLACEMENT
IN HARD/ROCKY TERRAIN (M)
7. Z PRESSURE/OVERPRESSURE (M)

3. MANUAL BACKUP FOR DEGRADED
PERFORMANCE. THIS MAY LIMIT
PERFORMANCE IN PROOF OF
PRINCIPLE DEMONSTRATION
4. MANUAL BACKUP (APRIL 87 IN HARDWARE)
5. POSITIVE RAM SYSTEM USING
EXTENDABLE ACUTATOR
6. SECONDARY JACK SYSTEM FOR PROOF
OF PRINCIPLE DEMO
7. DOUBLE EAR PROTECTION

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

RISK AREAS OF CONCERN

(CONTINUED)

POTENTIAL SOLUTIONS/ALTERNATES
COURSES OF ACTION

RISK AREAS

OPERATIONAL/RELIABILITY/SAFETY AREAS

8. MODIFIED RECOIL SYSTEM (M)

9. SPEED SHIFTING (M)

10. DIRECT FIRE (M)

11. MISFIRE PROCEDURES AT HIGH
ELEVATIONS (M)

12. PROPELLANT LOADING AT ELEVATIONS
ABOVE 600 MILS (M)

13. WEIGHT (M)

8. TESTING/MODELING VARIOUS
DESIGNS BEING DEVELOPED

9. SEVERAL OPTIONS ARE CURRENTLY
UNDER ANALYSIS

10. WE ACCEPT THE RISK ASSOCIATED
WITH DIRECT FIRE AT THIS LOW
HEIGHT

11. PULL SYSTEM 3 FT. OUT OF BATTERY

12. UTILIZATION OF AN ELEVATION
PLATFORM VS LOWERING TUBE TO
600 MILS WILL BE ANALYZED

13. -REDUCING COMPONENTS; COMBINING
FUNCTIONS; MONITORING WEIGHT BUDGETS;
USING COMPOSITES WHERE APPROPRIATE;
DYNAMIC SYSTEM ANALYSIS TO
UNDERSTAND INTERACTIONS

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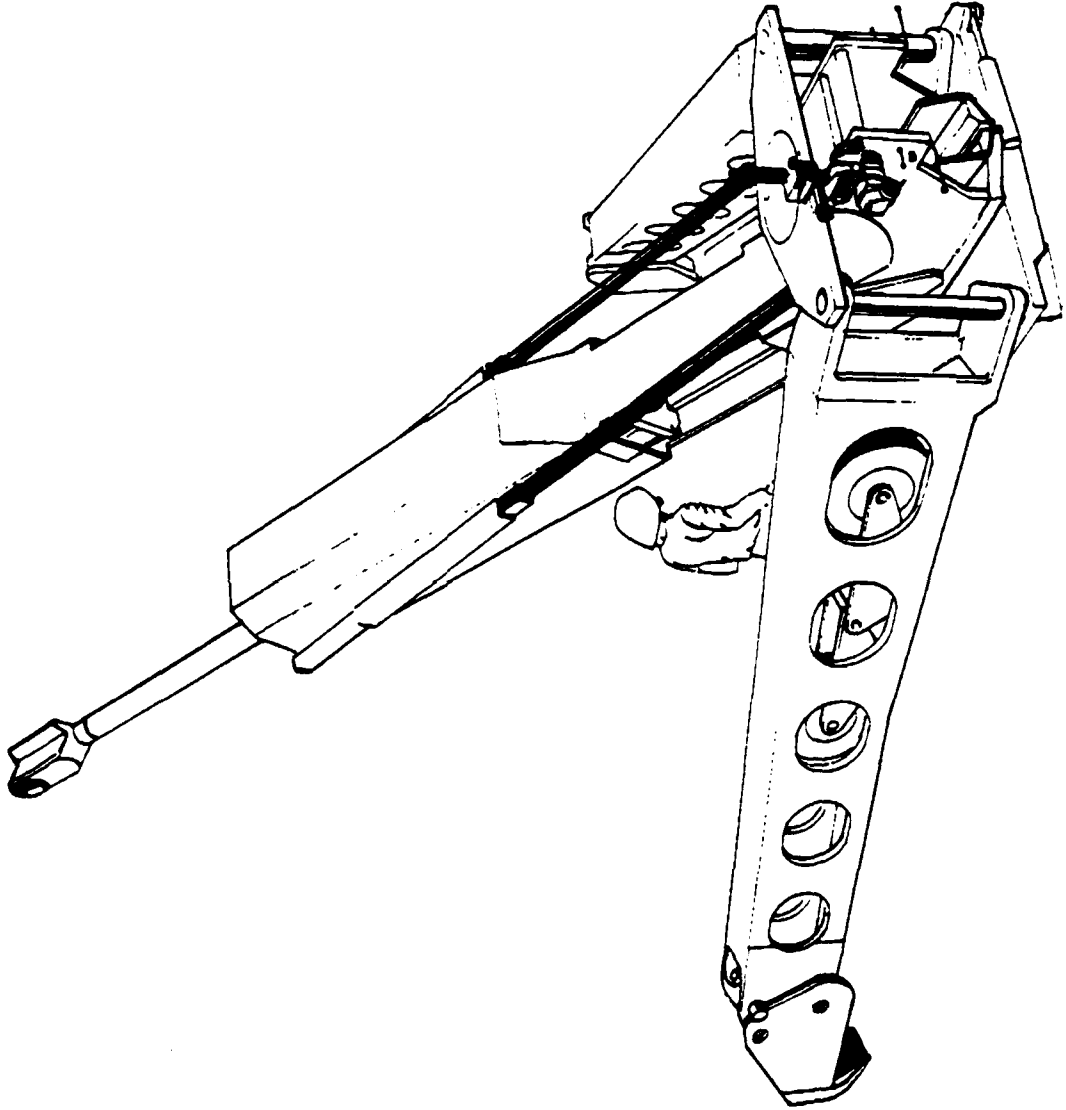
RESPONSES TO INITIAL PHASE II CRITICISM

| 0 - No change |
 | F - Favorable Effect |
 | U - Unfavorable Effect |

	Progress in the Areas of										RISK	
	COSTS			TIME		PERFORMANCE						
	Ph2	Ph3		Ph2	Ph3	OP	HF	STAB	WT	QA		RAM-D
Overall	0	F		0	F	FF	F	F	F	F	F	F
Load propellant with Cannoneer 1	0	F		0	F	F	U	0	0	F	F	F
Reconf. slide to fac. side acc.	f	ff		f	f	f	0	0	f	f	0	f
Move Cannon. 1 to beside breech	0	0		0	0	ff	u	0	0	0	f	f
Load 3 feet out of battery	u	u		u	0	0	0	0	u	0	u	0
Use platform for over 600 mills	u	u		u	0	u	u	0	u	0	0	0
Eliminate dolly	U	U		U	0	F	F	F	0	0	U	0
Move wheels into trails	u	u		u	0	f	f	uf	f	0	0	0
Add suby. to raise/lower wheels	u	u		u	0	0	0	f	u	0	u	0
Increase overall width to 108"	u	0		u	0	0	0	f	u	0	0	0
Simplify hydraulic system	F	F		FF	0	F	F	0	FF	0	F	0
All controls possible to front	0	f		f	0	f	f	f	f	0	f	0
Cannoneer 1 cont. to breech area	0	0		0	0	f	0	0	f	0	f	0
Adoption of joystick control for elev/tray												
Use of load tray as flick rammer	f	f		f	u	0	0	u	f	0	f	u
Eliminate mechanical propellant insertion	0	f		f	f	f	0	u	f	0	f	f
Minimization of honeycomb	0	0		0	0	0	0	0	U	F	F	0

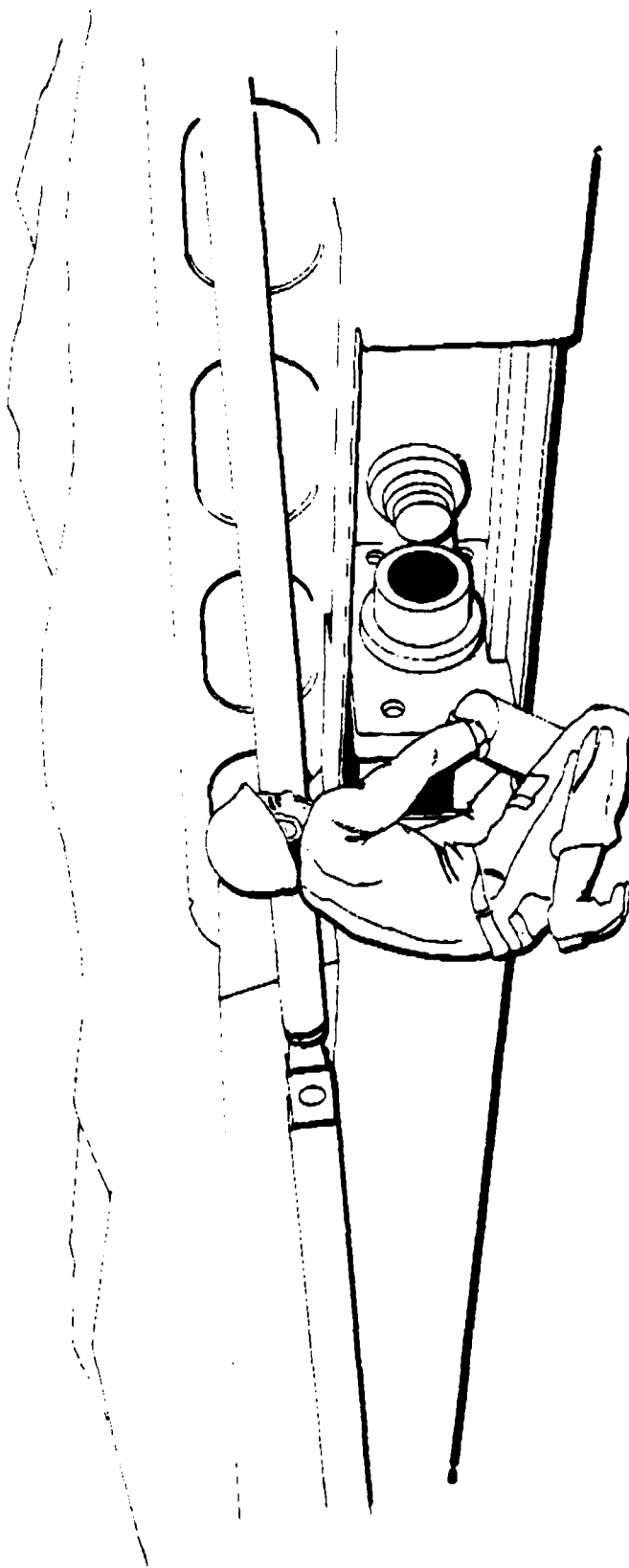
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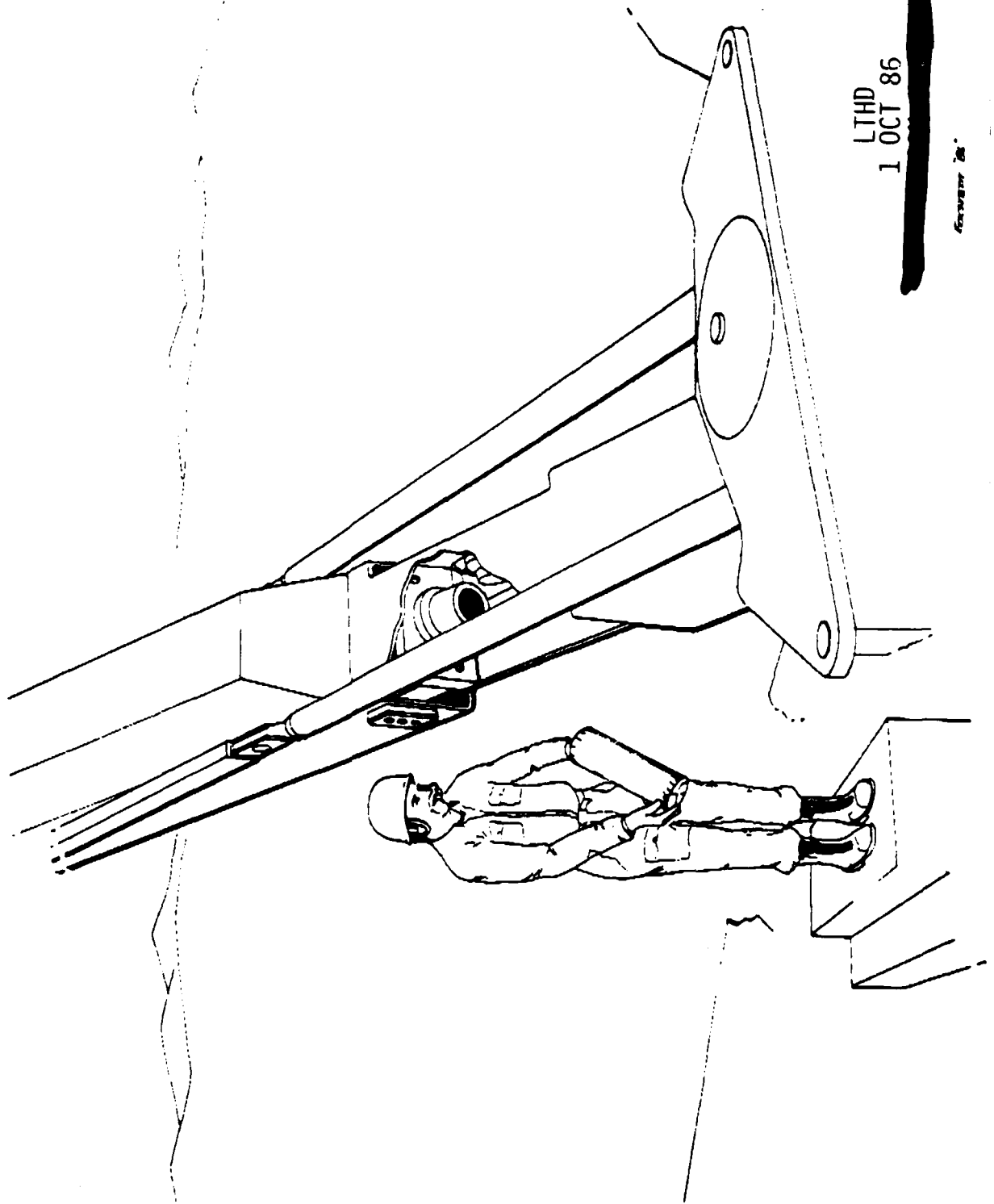
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Firearm '86

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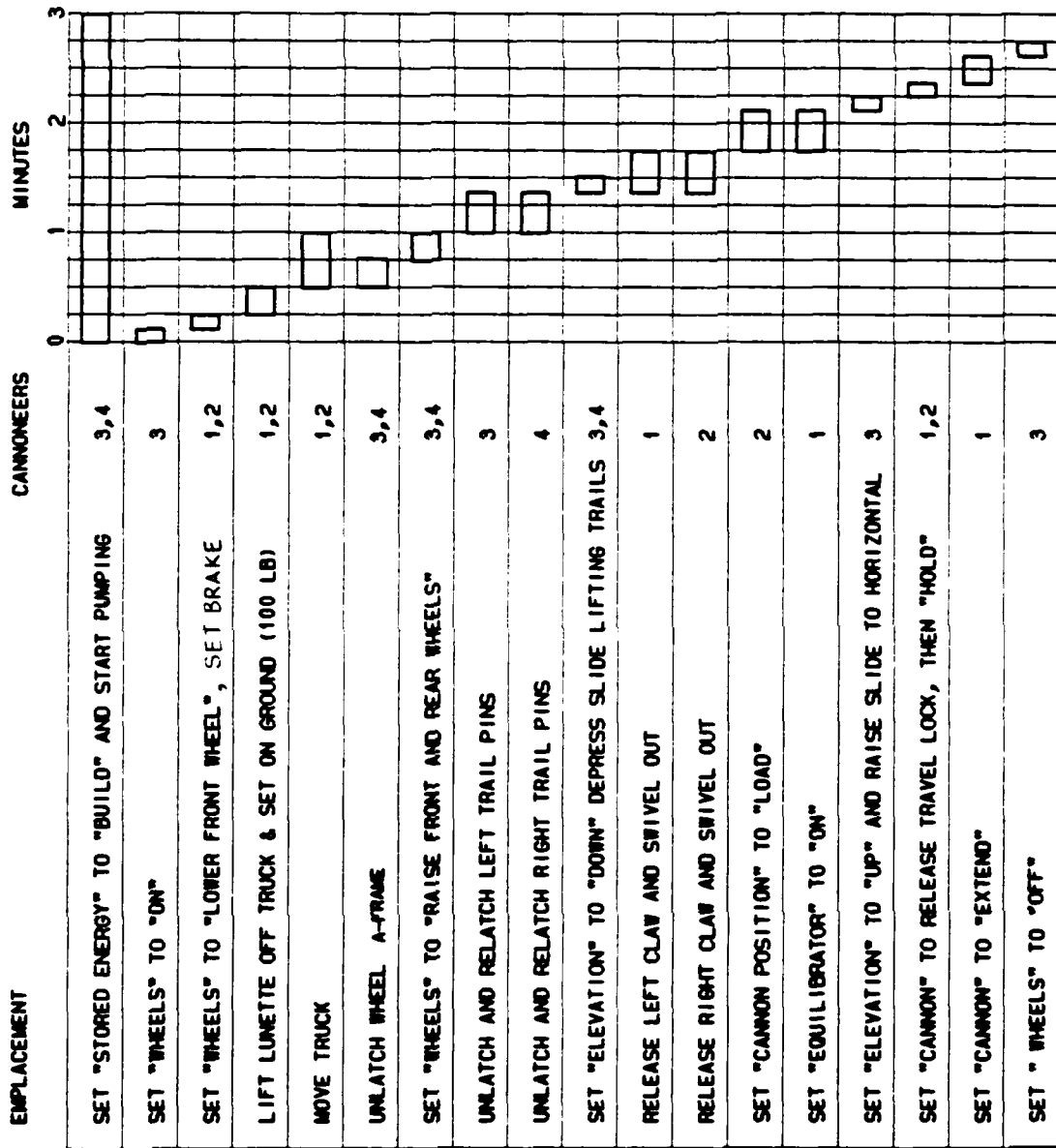
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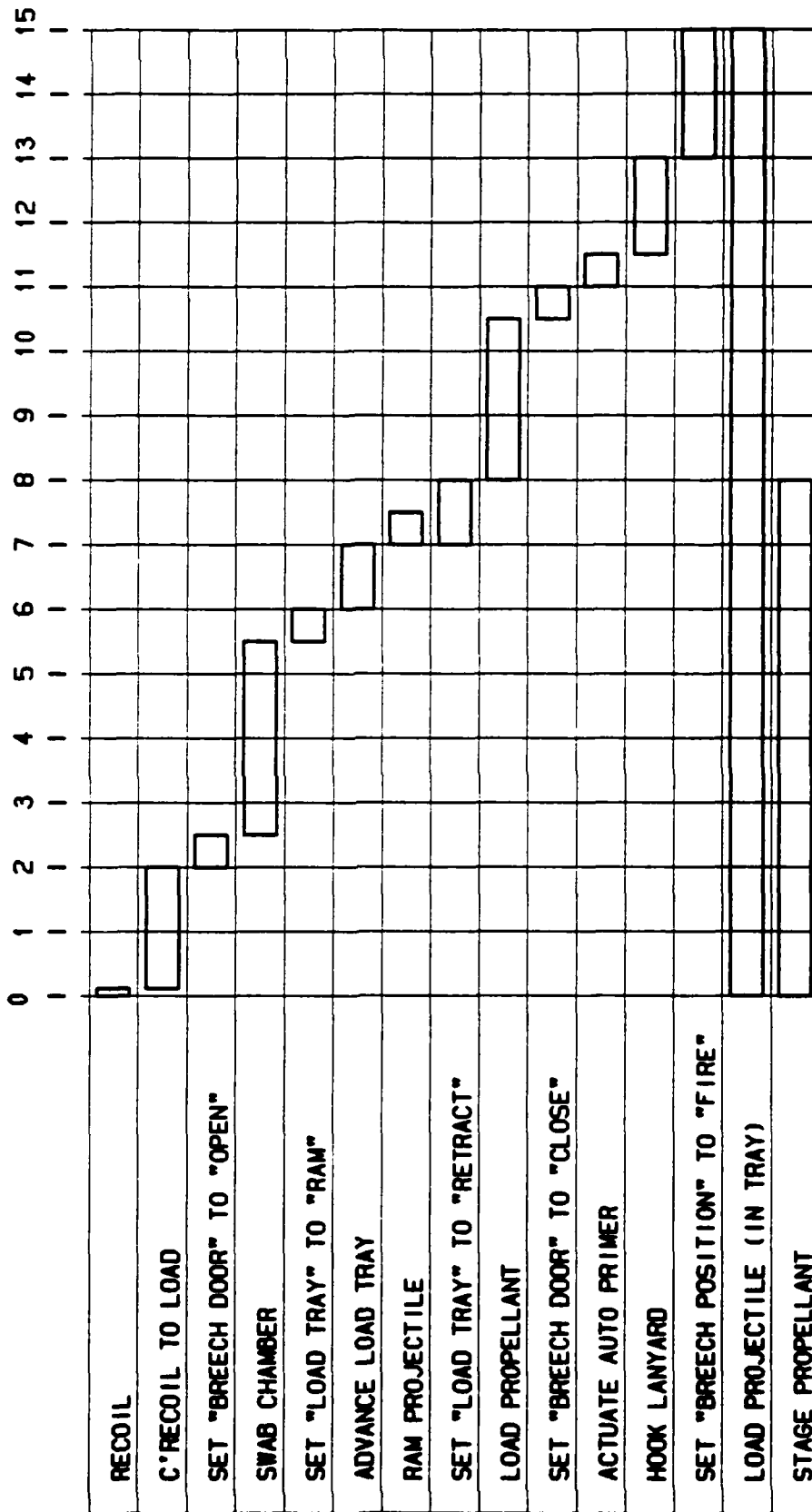


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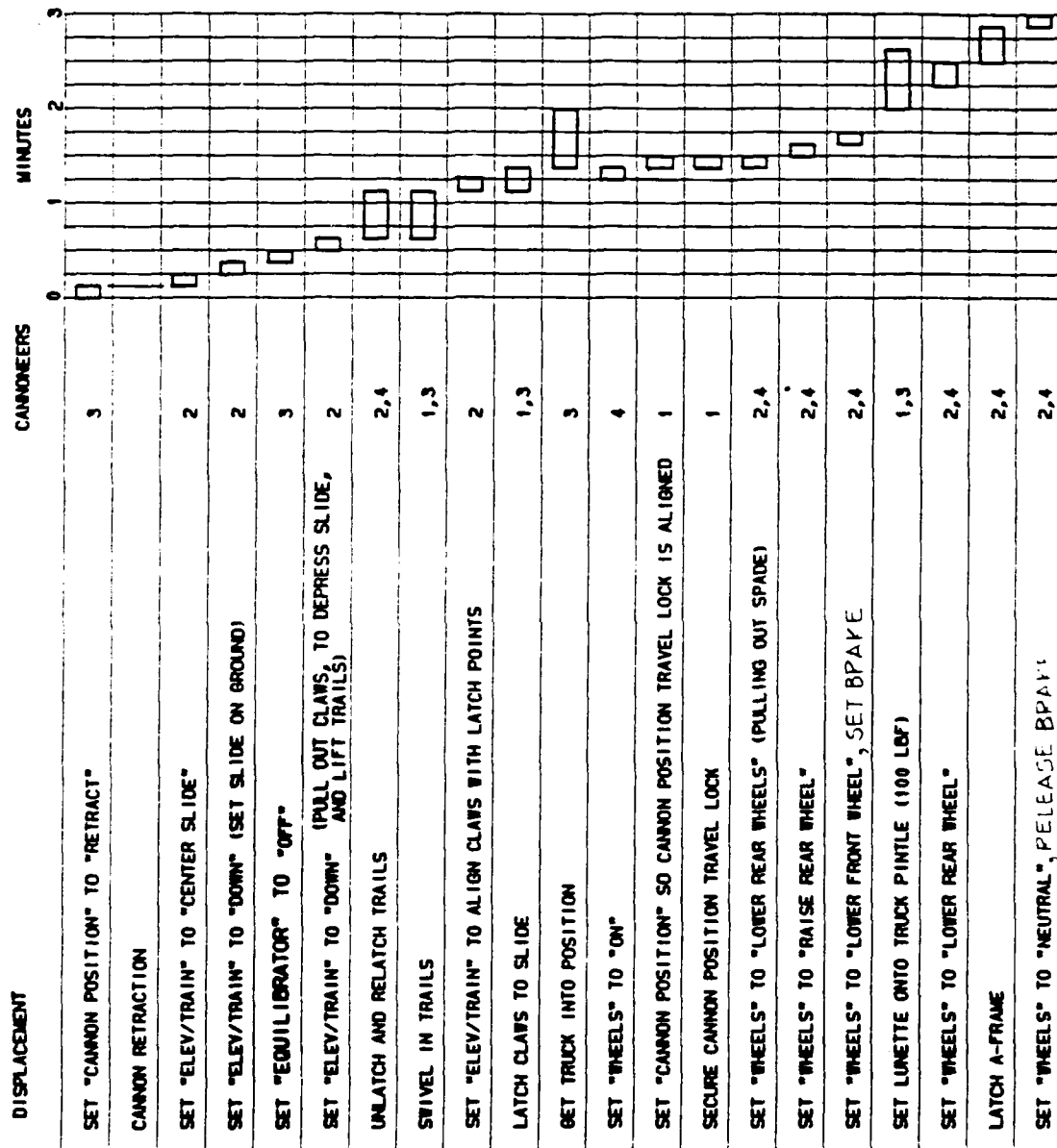
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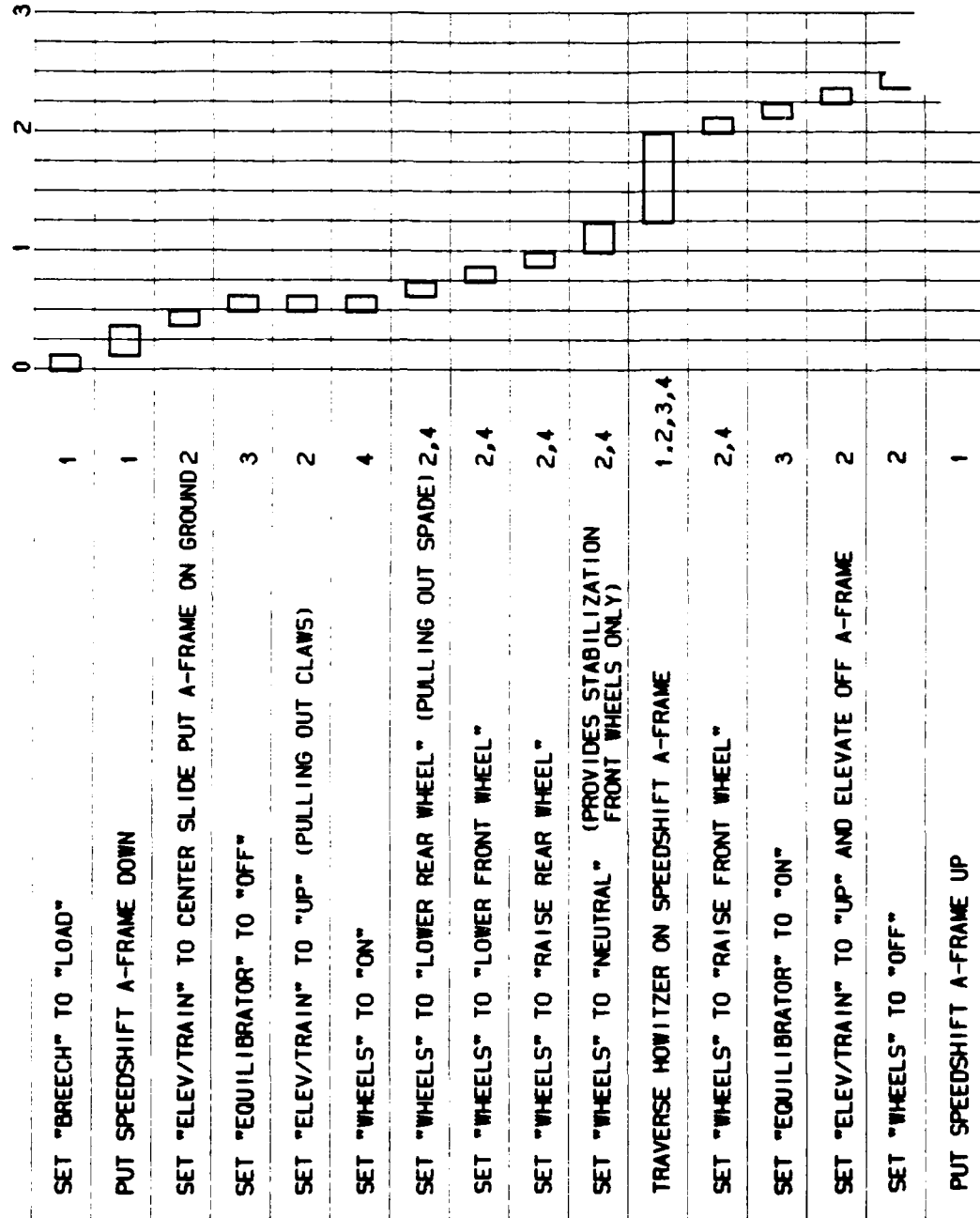
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SPEEDSHIFT

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MINUTES



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TECHNICAL PRESENTATION
PHASE II

3000 10/1/86
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155MM LIGHTWEIGHT TOWED HOWITZER DEMONSTRATION PROGRAM

CONTRACT DAAA21-86-C-0047

QUARTERLY PROGRAM REVIEW

29 OCTOBER 1986

AT ARDEC

PRESENTED BY:

ROBERT RATHE, PROGRAM MANAGER

BART ANDERSON, PROJECT ENGINEER

ERROL QUICK, SYSTEMS ENGINEER

SCOTT DACKO, ENGINEER

TOM RUDOLF, COMPOSITES ENGINEER

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29 OCTOBER 1986

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SCOPE AND PURPOSE

Quarterly Program Review and Design Review

DATE: Wednesday, October 29, 1986, at ARDEC - 8:30 am - 4:00 pm

REFERENCE: Design information provided informally on October 22, 1986, and quality program plan/test plan and reliability assessment provided on October 27, 1986

Objectives:

- o Review baseline design and critique design and analysis
- o Review program schedule and status and identify areas of concern

List of documents for review:

- o Program plan - provided update October 1, 1986
- o Quality assurance program plan - provide by October 27, 1986
- o Product assurance test program plan - provide by October 27, 1986
- o Layouts of components - provide by October 22, 1986
- o Hydraulic functional diagram - provide by October 22, 1986
- o Operational procedures - provide by October 22, 1986

Action items will be discussed at the end of each session.

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AGENDA FOR MEETING ON WEDNESDAY, OCTOBER 29, 1986

8:30 am	Introductions	Robert Rathe
8:35 am	Program Status	Robert Rathe
	Schedule Review	
	Financial Status	
	Problems Requiring Resolution	
	Future planned effort	
	Risk Assessment	
9:00 am	Operational Description/Requirement	Errol Quick
	Stability and Weight Update	
	<u>Preliminary Design Review with Analysis</u>	Bart Anderson
		Jeff Ireland
10:00 am	Cannon Assembly and Interface Drawings	
	Auto Primer	
	Recoil System Assembly	
11:00 am	Cradle Assembly	
12:00 noon	Lunch	
12:30 pm	Gimbal	
	Platform Assembly	
	Trail Assembly	
1:45 pm	Fire Control Assembly	
2:00 pm	Hydraulic System Review	
3:30 pm	Reliability Assessment	Errol Quick
	Quality Program Plan/Test Plan	
3:45 pm	Action Items and Wrap-Up	Robert Rathe
4:00 pm	Adjourn	

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DESCRIPTION	1986							1987			
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	
PHASE II TASKS:											
DEVELOP DETAILED DESIGN	X							X			
CONDUCT ANALYSES	X					X					
CONDUCT OPTIMIZATION			X			X			X		
PREPARE SCHEMATICS									X		
UPDATE SYSTEM SPECS						X				X	
PREPARE DRAWINGS											
DEVELOP CONTROL LOGIC			X			X					
SPECIFY MATERIALS				X			X				
SELECT FABRICATORS					X			X			
WRITE FAB/QA PROCEDURES					X						
DEVELOP PURCH. DESCRIPTION					X						
ORDER LONG LEAD ITEMS					X						
CONDUCT TRADE STUDIES											
DEVELOP MAT. TEST PLANS							X				
PREPARE TEST SAMPLES											
DEVELOP ACCEPTABLE PLAN											
DEVELOP R&M REQUIREMENTS											
DEVELOP QUAL. PROGRAM PLAN											
UPDATE DYN. ANALYSIS REPORT											
UPDATE PHA											
INTERNAL REVIEWS											
CUSTOMER REVIEWS	X	X	X	X		X			X	X	

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PROGRESS AGAINST PLANS FOR OCTOBER

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PLAN

1. VALIDATE LOAD CASES FOR INDIVIDUAL PART DESIGNS.
2. COMPLETE PRELIMINARY DESIGN OF CRADLE, TRAIL, GIMBAL, AND PLATFORM.
3. COMPLETE HYDRAULIC FUNCTIONAL SCHEMATIC INTERFACE DEFINITION FOR HYDRAULIC SYSTEM.
4. COMPLETE INTERFACE DEFINITION LAYOUTS FOR CANNON AND AUTO PRIMER FEED.
5. UPDATE WEIGHT BUDGETS BASED ON LATEST DESIGN.
6. SUBMIT PLANS FOR MATERIALS, SAMPLES AND TESTING FOR PHASE II.
7. SUBMIT PRELIMINARY PRODUCT ASSURANCE TEST PROGRAM PLAN.
8. COMPLETE PROJECT RELEASES FOR PHASE II. COMPLETE DETAILED SCHEDULE.
9. SUBMIT MODIFIED COST PROPOSAL AND PROPOSAL FOR RELIEF ON LEVEL II DRAWINGS IN AREA OF HYDRAULICS COMPONENTS.

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PROGRESS

LOAD CASES CALCULATED.
SYSTEM MODEL RESULTS DUE
30 OCTOBER 1986.
COMPLETE

COMPLETE

COMPLETE
REVISED DUE DATE OF 30
NOVEMBER 1986 FOR INTER-
FACE DRAWINGS.
COMPLETE

TO BE SUBMITTED BY 5
NOVEMBER 1986.
SUBMITTED 27 OCTOBER 1986.

27 OCTOBER 1986
24 OCTOBER 1986
WAITING FOR COST PROPOSAL
FROM YORK AND ESTIMATE OF
MATERIAL SAMPLE TEST BASED
ON MATERIALS SELECTED TO
BE SUBMITTED 5 NOVEMBER 1986

[REDACTED]

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PLANS FOR NOVEMBER

- 0 COMPLETE DETAILED BILL OF MATERIAL WITH ANALYSIS-DRIVEN WEIGHTS.
- 0 ORDER MATERIALS FOR MATERIALS TEST AND EVALUATION.
- 0 COMPLETE PRELIMINARY FEA SYSTEM MODELING TO VALIDATE STRUCTURAL INTEGRITY.
- 0 COMPLETE COARSE FEA FOR CRADLE, TRAILS, GIMBAL AND PLATFORM.
- 0 COMPLETE ANALYSIS OF RECOIL AND EQUILIBRATION SYSTEM.
- 0 COMPLETE INTERFACE DRAWINGS FOR CANNON.
- 0 DEVELOP LONG LEAD ITEM LIST AND IDENTIFY VENDORS FOR LONG LEAD PARTS.
- 0 COMPLETE STARTING POINT FEA MODEL OF MUZZLE BRAKE.
- 0 CONFIGURE AMMUNITION LOADING SYSTEM.
- 0 CONFIGURE FIRE CONTROL TRUNNION ASSEMBLY.
- 0 COMPLETE SOURCE CONTROL DRAWINGS FOR EQUILIBRATION AND TRAVERSE ACTUATORS.
- 0 COMPLETE DETAIL OF MUZZLE BRAKE.
- 0 COMPLETE DESIGN OF RECOIL/ENERGY RECOVERY SYSTEM.

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WRS Element	Description	Probability Factors			Consequence Factors			Avg. Prob. Factor	Avg. Consequ. Factor	Risk Rating
		P _a	P _c	P _d	C _t	C _c	C _s			
11100	Int/assy	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557
11200	Cannon Tube	0.3	0.3	0.5	0.3	0.3	0.3	0.367	0.390	0.557
	Muzzle Brake	0.3	0.3	0.5	0.3	0.3	0.3	0.367	0.390	0.557
	Breech	0.3	0.3	0.5	0.3	0.3	0.3	0.367	0.390	0.557
11300	Primer Autoloader	0.5	0.5	0.9	0.7	0.3	0.5	0.633	0.500	M-H
	Carriage	0.5	0.5	0.9	0.7	0.3	0.5	0.633	0.500	M-H
	Cradle	0.5	0.5	0.9	0.9	0.5	0.5	0.567	0.673	M-H
	Trails	0.7	0.5	0.5	0.9	0.5	0.5	0.567	0.673	M-H
	Siebel	0.5	0.5	0.5	0.5	0.5	0.5	0.500	0.500	M
	Platform	0.3	0.1	0.3	0.3	0.3	0.3	0.233	0.300	0.412
	Wheel units	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412
	Recoil Mechanism	0.5	0.5	0.9	0.7	0.5	0.5	0.633	0.567	M-H
	Equilibrators	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557
	Hydraulics	0.5	0.5	0.5	0.7	0.5	0.5	0.500	0.567	M-H
	Flick Rammer	0.7	0.5	0.5	0.7	0.3	0.3	0.567	0.433	M
	Load Tray	0.3	0.1	0.1	0.1	0.1	0.1	0.167	0.100	0.230
	Spade	0.3	0.1	0.3	0.7	0.3	0.3	0.233	0.433	0.566
	Claws	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557
11400	Fire Control									
	Elevation	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412
	Traverse	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412

P_a = probability of failure due to maturity
 P_c = probability of failure due to complexity
 P_d = probability of failure due to dependency on other items
 C_t = consequence of failure due to technical factors
 C_c = consequence of failure due to changes in cost
 C_s = consequence of failure due to changes in schedule

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RR

FMC

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR
RISK AREAS OF CONCERN

POTENTIAL SOLUTION/ALTERNATE
COURSES OF ACTION

RISKS

MATERIALS AREA

1. COMPOSITE MATERIAL (M - H)
2. TITANIUM USED IN GIMBAL/
MUZZLE BRAKE (M)

1. TESTING/QUALITY CONTROL/
SAMPLES/MODELING

2. USED MODIFIED STEEL MUZZLE
BRAKE WITH ATTACHED LUNETTE
AND A STEEL/COMPOSITE INSERT
IN THE GIMBAL

PERFORMANCE AREA

3. ENERGY RECOVERY SYSTEM (M)

3. MANUAL BACKUP FOR DEGRADED
PERFORMANCE. THIS MAY LIMIT
PERFORMANCE IN PROOF OF
PRINCIPLE DEMONSTRATION

4. PRIMER AUTOLOADER (M - H)

4. MANUAL BACKUP (APRIL 87 IN HARDWARE)

5. FLICK RAMMER (M)

5. POSITIVE RAM SYSTEM USING
EXTENDABLE ACUTATOR

6. SPADE EMPLACEMENT/DISPLACEMENT
IN HARD/ROCKY TERRAIN (M)

6. SECONDARY JACK SYSTEM FOR PROOF
OF PRINCIPLE DEMO

7. Z PRESSURE/OVERPRESSURE (M)

7. DOUBLE EAR PROTECTION

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FMC

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

RISK AREAS OF CONCERN

(CONTINUED)

POTENTIAL SOLUTIONS/ALTERNATES

COURSES OF ACTION

RISK AREAS

OPERATIONAL/RELIABILITY/SAFETY AREAS

8. MODIFIED RECOIL SYSTEM (M)

9. SPEED SHIFTING (M)

10. DIRECT FIRE (M)

11. MISFIRE PROCEDURES AT HIGH ELEVATIONS (M)

12. PROPELLANT LOADING AT ELEVATIONS ABOVE 600 MILS (M)

13. WEIGHT (M)

8. TESTING/MODELING VARIOUS DESIGNS BEING DEVELOPED

9. SEVERAL OPTIONS ARE CURRENTLY UNDER ANALYSIS

10. WE ACCEPT THE RISK ASSOCIATED WITH DIRECT FIRE AT THIS LOW HEIGHT

11. PULL SYSTEM 3 FT. OUT OF BATTERY

12. UTILIZATION OF AN ELEVATION PLATFORM VS LOWERING TUBE TO 600 MILS WILL BE ANALYZED

13. -REDUCING COMPONENTS; COMBINING FUNCTIONS; MONITORING WEIGHT BUDGETS; USING COMPOSITES WHERE APPROPRIATE; DYNAMIC SYSTEM ANALYSIS TO UNDERSTAND INTERACTIONS

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

BRIEFING OUTLINE

- 0 PRIMARY OBJECTIVE
- 0 DESIGN OBJECTIVES
- 0 DESIGN SPECIFICATIONS (STATUS)
- 0 UPDATED AREAS FOR THE PHA

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

PRIMARY OBJECTIVE

TO CONCEPTUALIZE, DESIGN AND FABRICATE A 155MM TECHNOLOGY
DEMONSTRATOR WHICH CAN MEET OR EXCEED THE PERFORMANCE
CHARACTERISTICS OF THE M198 HOWITZER, BUT IN A MUCH
LIGHTER CONFIGURATION. (9000 LBS VS. 15,760 LBS).

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR



DESIGN OBJECTIVES

THE LTHD DESIGN OBJECTIVES ARE TO MAXIMIZE SYSTEM EFFECTIVENESS, RELIABILITY, FLEXIBILITY, SAFETY, SIMPLICITY AND MAINTAINABILITY WHILE MINIMIZING THE OVERALL SIZE, WEIGHT, VULNERABILITY AND COST.

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR



DESIGN SPECIFICATIONS

DESCRIPTION

SOW PARA

REQUIREMENT

LTHD STATUS

PHYSICAL CHARACTERISTICS

0 SIZE

C.2.B.B

OVERALL SIZE SHOULD BE NO
LARGER THAN CURRENT M198
ENVELOPE VOLUME.

MET

00 STOWED CONFIGURATION

IMPLIED (C130
CONSTRAINT)

38' 9'2" x 7

28'6" x 9' x 7'3"

00 TOWING CONFIGURATION

IMPLIED M198

40'3" x 9'2" x 9'6"

28'6" x 9' x 7'3"

00 FIRING CONFIGURATION

IMPLIED M198

37'2" x 25'9" x 9'6"

REQUIRE 39 1/4
FOOT DIAMETER
CIRCULAR AREA

0 WEIGHT

C.2.B.A

NOT GREATER THAN 9000 LBS

EXPECT TO MEET
REQUIREMENT

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR



DESIGN SPECIFICATIONS

DESCRIPTION

SOW PARA

REQUIREMENT

LTHD STATUS

DESIGN

0 STANDARDIZATION

C.2.B.D

INCORPORATE STANDARD
MILITARY PARTS, MATERIALS,
HARDWARE TO MAXIMUM EXTENT
POSSIBLE

WILL BE INCORPORATED
TO MAXIMUM EXTENT
POSSIBLE

0 PRODUCIBILITY

SELF-
IMPOSED

CONSIDER PRODUCIBILITY SO
PARTS CAN BE MANUFACTURED
WITHOUT ELABORATE MACHINERY
OR RARE SKILLS. EXOTIC
MATERIALS REQUIRING SPECIAL
MACHINING OR TREATING SHOULD
BE AVOIDED

WILL BE INCORPORATED
INTO DESIGNS

0 SPECIAL REQUIREMENTS

C.2.A.G

MAINTAIN BALLISTIC SIMILITUDE
WITH M198 TO THE EXTENT
PRACTICAL

LTHD WILL HAVE A
DIFFERENT FIRING
TABLE

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR



DESIGN SPECIFICATIONS

DESCRIPTION
DESIGN (CONTINUED)

SOW PARA #

REQUIREMENT

LTHD STATUS

C.2.B.C

MAXIMUM IMPULSE
IMPARTED TO RECOIL
MECHANISM IS 12,500 LBS SEC

≥ 12,500 LB-SEC

SELF-
IMPOSED

STANDARD HYDRAULIC FLUID
SHALL BE USED PER MIL-STD
6083

MET

IMPLIED
M198

LTHD DESIGN SHALL INTEGRATE
AND EFFECTIVELY INTERFACE
WITH GFE

CAN BE MET

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

<u>DEPLOYMENT</u>	<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
0	FIXED WING TRANSPORT	IMPLIED M198	BE CAPABLE OF BEING LOADED TRANSPORTED AND DEPLOYED FROM FROM C-130E, C-141 AND C-5 AIRCRAFT	MET
0	AIR DROPPABLE AND LOW ALTITUDE PARACHUTE EXTRACTION SYSTEM (LAPES)	C.2.A.C. IMPLIED	MUST BE AIR DROPPABLE AND LAPES CERTIFIED MUST BE CAPABLE TO WITHSTAND IMPACT SHOCK LOADS OF 15-20 G'S	TBD
0	AIRLIFTABLE BY HELICOPTER	C.2.A.H	MUST BE TRANSPORTABLE BY UH60 BLK I MOD HELICOPTER	TBD

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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DESIGN SPECIFICATIONS

<u>DESCRIPTION</u> <u>DEPLOYMENT (CONTINUED)</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
0 VEHICLE INTERFACE			
	IMPLIED M198	AIRLIFTABLE BY CH-47 OR LARGER HELICOPTER	MET
	C.1.A. IMPLIED M198	SHALL BE CAPABLE OF BEING TOWED BY DESIGNATED TACTICAL VEHICLES (M813, M548, M992)	MET
	IMPLIED M198	MUST HAVE A MINIMUM GROUND CLEARANCE OF 10.5 INCHES	>10.5 IN
	SELF-IMPOSED	SHOULD HAVE A TURNING RADIUS OF TBD	

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

REQUIREMENT

LTHD STATUS

SOW PARA #

DESCRIPTION

TACTICAL MOBILITY

PAST ANALYSIS
INDICATES STABILITY

MUST REMAIN STABLE UNDER
ALL TOWING CONDITIONS

C.2.A.A

0 TOWING SPEED/STABILITY

BUILT INTO DESIGN

MUST HAVE ROUGH TERRAIN
CROSS-COUNTRY CAPABILITIES

C.2.A.D

PAST ANALYSIS
INDICATES STABILITY

THE LTHD SHALL REMAIN STABLE
AT THE MAXIMUM TOWING

IMPLIED M198

SPEEDS OF:

- 0 CROSS COUNTRY - 5 MPH
- 0 SECONDARY ROADS - 25-30 MPH
- 0 IMPROVED ROADS - 45 MPH

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

DESCRIPTION

TACTICAL MOBILITY (CONTINUED)

SOW PARA

REQUIREMENT

LTHD STATUS

0 FIRING POSITION

IMPLIED M198

DEPLOY AND FIRE LTHD FROM ANY
POSITION USED TO TO FIRE M198
SITUATIONS WHERE M198
0 DEPLOY ON ALL TYPES OF
TERRAIN

0 DEPLOYABLE WITHIN A
CIRCULAR AREA OF 37 FEET
IN DIAMETER

VERBAL REG
ARDEC

LOAD AND FIRE FROM MAXIMUM
TERRAIN SLOPE = 10° GRADE

0 WEAPON EMPLACEMENT

C.2.A.E

MUST BE ABLE TO BE EMPLACED
BY A MINIMAL CREW OF 4 PERSONS THAT REQUIREMENT CAN
IN 3 MINUTES OR LESS (ASSUME BE MET
WEAPON HAS BEEN DISCONNECTED
FROM HELICOPTER OR TRUCK)

TIMELINES INDICATE

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

DESCRIPTION

TACTICAL MOBILITY (CONTINUED)

SOW PARA

REQUIREMENT

LTHD STATUS

0 WEAPON DISPLACEMENT

SELF-IMPOSED
IMPLIED BY SOW

DISPLACED BY 4-PERSON CREW
IN 3 MINUTES OF LESS (TIME
DOES NOT INCLUDE ATTACHING
THE LTHD TO THE TOWING
VEHICLE) NOTE: THIS ACTION
WAS NOT REQUIRED BY THE SOW

TIMELINES INDICATE
THAT WE ARE CURRENTLY
7 SECONDS OVER

0 SPEED SHIFTING

C.2.A.E

A 4-PERSON CREW MUST BE ABLE
TO SHIFT THE LTHD THROUGH
6400 MILS IN 3 MINUTES OR
LESS

TIMELINES INDICATE
THAT REQUIREMENT
CAN BE MET

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

<u>DESCRIPTION</u> <u>FIRE POWER</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
0 ELEVATION	IMPLIED M198	ELEVATE BETWEEN THE LIMITS OF -75 TO 1275 MILS	INCORPORATED INTO DESIGN
0 TRAVERSE	IMPLIED M198	TRAVERSE 400 MILS TO THE RIGHT OR LEFT OF THE EMPLACEMENT ORIENTATION	INCORPORATED INTO DESIGN
0 MAX RATE OF FIRE	C.1.A. IMPLIED	MUST ACHIEVE FOLLOWING MAXIMUM FIRING RATES FOR STANDARD SIZE ROUNDS <div> <div>< 800 MILS - 4 RDS/MIN</div> <div>> 800 MILS - 1 RD/MIN</div> </div>	TIMELINES INDICATE THAT REQUIREMENT COULD BE MET
	IMPLIED M198	OVERSIZED ROUNDS (COPPERHEAD) - TBD TBD	

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR



DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>FIRE POWER (CONTINUED)</u>			
0 SUSTAINED RATE OF FIRE	SELF-IMPOSED	MAINTAIN MAX RATE OF FIRE FOR UP TO TBD* MINUTES	TBD
0 SUSTAINED RATE OF FIRE	IMPLIED M198	MUST BE CAPABLE OF MAINTAINING TBD A SUSTAINED RATE OF FIRE OF TBD* ROUNDS PER MINUTE	
0 RANGE	C.2.A.6	RANGE MUST BE AT LEAST EQUAL TO OR BETTER THAN CURRENT M198	ANALYSIS INDICATES REQ CAN BE MET
	IMPLIED M198	MINIMUM RANGE CAPABILITY OF 3.5 KM OR LESS	ANALYSIS INDICATES REQ. CAN BE MET

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>FIRE POWER (CONTINUED)</u>			
	IMPLIED M198	MUST HAVE A DIRECT FIRE CAPABILITY THAT IS AT LEAST EQUIVALENT TO M198	WILL NOT MEET - TRUNNION HEIGHT IS LOWER

*BENET LABS TO DETERMINE

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>FIRE POWER (CONT)</u>			
0 PROJECTILE DELIVERY ERROR	IMPLIED M198	DELIVER SPECIFIED PROJECTILES ON TARGET AT THE LEVEL OF PRECISION CURRENTLY DEMONSTRATED BY M198. SHALL NOT EXCEED 3 MIL CEP AT MAXIMUM RANGE	TBD
0 FIRING STABILITY	C.2.A.A	MUST REMAIN STABLE UNDER ALL FIRING CONDITIONS.	POST ANALYSIS INDICATES STABILITY
	IMPLIED M198	THE SKID AND HOP REACTIONS TO FIRING SHALL NOT EXCEED THOSE OF M198	TBD
0 FIRE CONTROL	IMPLIED	LTHD SHALL INCORPORATE THE M198 FIRE CONTROL SYSTEM (GFE)	INCORPORATED INTO DESIGN
<u>AMMUNITION INTERFACE</u>			
0 PROJECTILES	C.2.A.F	BE CAPABLE OF LOADING AND FIRING ALL CONVENTIONAL AND IMPROVED 155MM PROJECTILES	MET--EXCEPT LOADING FOR COPPERHEAD AND NUCLEAR ROUNDS WILL HAVE TO BE INVESTIGATED

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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DESIGN SPECIFICATIONS

DESCRIPTION	SOW PARA #	REQUIREMENT	LTHD STATUS
AMMUNITION INTERFACE (CONT)			
0 CHARGES	IMPLIED BY C.2.A.F	BE ABLE TO LOAD AND FIRE CURRENT 155MM PROPELLING CHARGES PLUS UNIQUE CHARGE (M454 NUCLEAR PROJ) AND MODULAR CHARGE (UNDER DEVELOPMENT)	MET TBD (MOD CHARGE)
0 FUZES	IMPLIED BY C.2.A.F.	BE CAPABLE OF FIRING PROJECTILE/ FUZE COMBINATIONS WHICH ARE CURRENTLY FIRED FROM THE M198	MET
0 PRIMER	SELF IMPOSED	MAKE ALLOWANCES FOR AN AUTOMATIC PRIMER INSERTION CAPABILITY	WILL BE INCORPORATED INTO DESIGN
0 POST FIRE ACTIVITIES	IMPLIED M198	LOAD NEXT ROUNDS WITHIN TIME BUDGET ASSOCIATED WITH ACHIEVEMENT OF MAX RATE OF FIRE	TIMELINES INDICATE THAT REQ CAN BE MET
	IMPLIED M198	CAPABLE OF BEING SWABBED BETWEEN EACH ROUND	MET

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

DESCRIPTION

SOW PARA # REQUIREMENT

LTHD STATUS

POST FIRE ACTIVITIES (CONT)

0 ABNORMAL ACTIVITIES

C.2.A.B

DESIGN SHALL ENABLE DEVELOPMENT OF SAFE, EFFECTIVE PROCEDURES TO HANDLE:

PROCEDURES WILL BE PREPARED. DESIGN WILL ENSURE THAT ALL SITUATIONS CAN BE HANDLED

C.2.A.B

** MISFIRES

IMPLIED M198

** HANG FIRES (NOT IN SOW)

IMPLIED M198

** STICKERS (NOT IN SOW)

C.2.A.B

** COOKOFF SITUATIONS

RECOIL WILL HANDLE ANY COOKOFF SITUATION

ENVIRONMENT

0 NATURAL ENVIRONMENT

MUST BE CAPABLE TO PERFORM ITS MISSION AND OPERATE EFFECTIVELY UNDER THE FOLLOWING CONDITIONS:

LTHD DESIGN SHOULD MEET THESE REQUIREMENTS

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>ENVIRONMENT (CONT)</u>			
	C.1.B.A	OPERATING TEMPERATURE: -25°F TO +160°F (UP TO 8 HOURS)	
	C.1.B.B	STORAGE TEMPERATURE: -70°F TO +160°F (FOR EXTENDED PERIODS)	
	C.1.B.I	TEMPERATURE SHOCK: PER MIL STD-810D METHOD 503	TBD
	C.1.B.C	HUMIDITY: NO DEGRADATION IN PERFORMANCE DURING OR AFTER EXPOSURE OF AMBIENT RELATIVE HUMIDITY OF UP TO 99% PER MIL STD 810D PROCEDURE V	DESIGN WILL ENSURE THAT ALL REQUIREMENTS ARE MET
	C.1.B.J	WATERPROOFNESS: PER MIL STD 810D METHOD 512.2	DESIGN WILL ENSURE THAT ALL REQUIREMENTS ARE MET
	C.1.B.H	DUST: PER MIL STD 810D METHOD 510, PROCEDURE 1	DESIGN WILL ENSURE THAT ALL REQUIREMENTS ARE MET
	IMPLIED	BE CAPABLE OF PERFORMING ALL LTHD FUNCTIONS UNDER ADVERSE WEATHER CONDITIONS	TBD

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>SELF-INDUCED ENVIRONMENT</u>			
0 SHOCK	C.1.B.D	MUST BE ABLE TO OPERATE IN THE SUSTAINED HIGH SHOCK AND VIBRATION ENVIRONMENT ASSOCIATED WITH THE TRAVEL OF A TOWED VEHICLE (MIL STD 810D METHOD 514.2 (GUIDE)	TBD
		WITHSTAND REPEATED GUN FIRING SHOCK CONDITIONS ANALYSIS	MET
0 VIBRATION	C.1.B.E	SINUSOIDAL VIBRATIONS OF .40 INCH DOUBLE AMPITUDE FROM 1 TO 14HZ AND 4G FROM 14HZ TO 500HZ AT THE COMPONENT MOUNTING INTERFACE. VIBRATION FREQUENCY WILL BE IMPOSED AT A LOGARITHMIC SWEEP RATE OF 20 MINUTES PER SWEEP CYCLE (FROM 5 TO 500 TO 5HZ) FOLLOWED BY 20 MINUTE DWELLS AT EACH RESONANT FREQUENCY (MAX OF 4 FREQ). TOTAL VIBRATION TIME INCLUDING DWELLS SHALL BE 120 MINUTES.	DIFFICULT REQUIREMENT TBD

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>SELF-INDUCED ENVIRONMENT</u> (CONT)			
0 CHEMICALS	C.1.B.F	WITHSTAND EXPOSURE TO VAPORS OR CONTACT WITH FOLLOWING FOR DURATIONS UP TO 48 HOURS: ** FUEL PER VV-F-800, MIL-T-5624, 1 MIL-E-3056 AND MIL-F-16884. ** HYDRAULIC FLUID PER SPEC. MIL-STD-6083D. ** CLEANING AGENTS PER P-C-437.	REQUIREMENT CAN BE MET
0 CLEANING SPRAY	C.1.B.G	WITHSTAND WATER JET SPRAY FROM 12 INCHES AWAY (PERPENDICULAR TO SURFACE)	REQUIREMENT CAN BE MET
<u>THREAT IMPOSED ENVIRONMENT</u>			
0 VULNERABILITY	SELF IMPOSED	VULNERABILITY TO FRAGMENTS FROM AERIAL BURSTS SHOULD BE PRIMARY CONSIDERATION FOR DESIGN DECISIONS AND TRADEOFFS INVOLVING COMPONENT PLACEMENT AND ROUTING OF CABLES/HOSES	TBD DESIGN WILL TRY TO ENSURE CRITICAL PARTS ARE PROTECTED

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>THREAT IMPOSED ENVIRONMENT</u> (CONT)			
0 FIRE RETARDANCY	SELF IMPOSED	MUST BE A DESIGN CONSIDERATION ESPECIALLY WHEN COMPOSITE MATERIALS ARE USED	IS A DESIGN CONSIDERATION FOR THE SELECTION OF MATERIALS
<u>MANUAL INTERFACE</u>			
0 CREW	IMPLIED M198	LTHD SHALL BE OPERATED BY A CREW OF NO MORE THAN 11 PERSONNEL. MANUAL TASKS ASSOCIATED WITH OPERATIONS SHALL BE COMPATIBLE WITH THE RANGE OF HUMAN CAPABILITIES OF THE 5TH TO 95TH PERCENTILE OF THE USA MALE POPULATION	CAN BE MET
<u>HUMAN FACTORS</u> <u>CONSIDERATIONS</u>			
0 NOISE/BLAST OVERPRESSURE	IMPLIED	DESIGN SHALL REFLECT HF ENGINEERING WHICH WILL ALLOW CREW/MAINTENANCE PERSONNEL TO PERFORM DESIGNED TASKS UNDER BATTLEFIELD CONDITIONS	TBD DESIGN WILL TRY TO MEET ALL REQ
	C.2.D.1	NOISE AND BLAST OVERPRESSURE WILL CONFORM TO MIL STD 1474 AND MIL HANDBOOK 759	SAME AS M198

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

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DESIGN SPECIFICATIONS

DESCRIPTION

SOW PARA

REQUIREMENT

LTHD STATUS

HUMAN FACTORS CONSIDERATIONS (CONT)

0 ELEVATION/TRVERSE
CONTROLS

C.2.D.2

DESIGN OF CONTROLS AND ACTIVATION
MECHANISM SHALL CONFORM WITH MIL
STD 1472 AND MIL HANDBOOK 759

TBD

0 MOPP IV AND ARCTIC

C.2.D.3

DESIGN SHALL DEMONSTRATE THAT
OPERATION/MAINTENANCE/REPAIR UNDER
MOPP IV AND ARCTIC CONDITIONS ARE
FEASIBLE

TBD

0 EDUCATIONAL

C.2.D.5

DESIGNERS SHALL MAKE EVERY EFFORT
TO ENSURE THAT LTHD COULD BE
OPERABLE/MAINTAINABLE/REPAIRABLE
BY SOLDIERS IN EDUC. CATEGORIES 1-4

TECH DEMO DIFFICULT
TO PROVE OUT

0 DISTANCES/ACCESS/
LIFT

C.2.D.6

REACH DISTANCES, VISUAL ACCESS AND
LIFTING REQUIREMENTS SHALL CONFORM
TO MIL-STD-1472 AND MIL HB 759

DESIGNERS ARE AWARE OF
REQUIREMENTS
TBD

0 FIRE CONTROL/
COMMUNICATION

C.2.D.7

FIRE CONTROL AND COMMUNICATION
DESIGN INTERFACES SHALL BE
CONSIDERED IN PHASE 2. COMPONENTS
SHALL BE DESIGNED IN CONFORMANCE
WITH MIL-STD-1472 AND MIL HB 759

TBD

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LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR



DESIGN SPECIFICATIONS

<u>DESCRIPTION</u>	<u>SOW PARA #</u>	<u>REQUIREMENT</u>	<u>LTHD STATUS</u>
<u>MANUAL BACKUP</u>	IMPLIED	LTHD DESIGN SHALL PROVIDE MANUAL BACKUP OPERATING MODES (MISSION CRITICAL FUNCTIONS) TO THE MAXIMUM EXTENT POSSIBLE.	MANUAL BACKUP WILL BE PROVIDED TO THE MAXIMUM EXTENT POSSIBLE
<u>MAINTENANCE AND SUPPORT OF LTHD</u>			
0 RELIABILITY/ MAINTAINABILITY	C.2.A.1	LTHD SHALL MAINTAIN M198 RELIABILITY AND MAINTAINABILITY REQUIREMENTS* IN ACCORDANCE WITH MIL STD 7850 AND MIL-STD-470A	
		LTHD RELIABILITY REQUIREMENTS:	
SELF IMPOSED		0 CORRECTIVE MAINTENANCE MRBF = TBD ROUNDS	TBD
IMPLIED M198		0 COMBAT ABORT MRBF = 1100 ROUNDS	TBD
		LTHD MAINTAINABILITY REQUIREMENTS:	
IMPLIED M198		MTTR (ORGANIZATIONAL MAINTENANCE) = 0.5 HOURS (DIRECT SUPPORT) = 2.0 HOURS	TBD

*NOTE: M198 PERFORMANCE (AS CALLED FOR IN THE SOW) HAS BEEN REPLACED BY M198 R&M REQUIREMENTS.

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AREAS TO BE UPDATED FOR PHA

PROBLEM

EXPOSURE TO BLAST OVERPRESSURE DAMAGES HEARING, LUNGS, SINUSES. CANNONEER NO 1 HAS THE WORST EXPOSURE.

RECOMMENDATION

TEST TO DETERMINE PRESSURE LEVELS AT CREW POSITIONS. PROVIDE E-A-R TYPE EARPLUGS AND HELMETS WITH ACOUSTICAL MUFFS. LIMIT EXPOSURE BY FIRINGS PER DAY DEPENDING ON ZONE FIRED SIMILAR TO M198. INCLUDE EAR PLUGS AND HELMETS WITH MUFFS IN THE APPROPRIATE AUTHORIZATION DOCUMENT.

IN THE TRANSPORT POSITION THE WHEELS ON ONE SIDE RAISE THE HOWITZER TO MAXIMUM HEIGHT WHILE THE OTHER SIDE REMAINS RESTING ON THE GROUND. SIDEWAYS INSTABILITY CAUSES TIPOVER.

THE UNIT MUST HAVE POSITIVE SIDE STABILITY IN WORST CASE: THE HOWITZER IS STABLE UP TO 27 DEGREES SIDE SLOPE IN THE WORST CASE CONDITION WITH ONE SIDE ELEVATED.

IN SEVERAL INSTANCES IT IS REQUIRED FOR PEOPLE TO WORK UNDER THE UNIT WHEN IT IS SUPPORTED ONLY BY HYDRAULICS - DIGGING HOLE FOR SPADE, LATCHING SPEED SHIFT A FRAME - A SUDDEN HYDRAULIC FAILURE COULD RAPIDLY LOWER THE HOWITZER.

CYLINDERS ARE PROVIDED WITH BEAR LOCKS. REDUNDANT CYLINDERS ARE USED SO THAT IN THE EVENT OF ONE FAILURE THE SECOND CYLINDER CAN SUPPORT THE LOAD

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29 OCTOBER 1986
EQ

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PROBLEM

SHOCK, VIBRATION OR INADVERTENT ACTUATION BY
SOLDIERS CLIMBING OVER EQUIPMENT CAUSES SUDDEN
OR UNEXPECTED ACTUATION OF HYDRAULIC UNITS

RECOMMENDATION

CRITICAL VALVES TO HAVE A LATCH OR NEUTRAL
LOCK TO PREVENT UNEXPECTED FUNCTION

IN THE REMOVAL OF THE SPADE FROM THE GROUND IF
THE SPADE STICKS IN THE GROUND THE UNIT WILL
FULCRUM ON THE REAR WHEELS. MAY LEAD SOLDIERS
TO ATTEMPT TO PULL DOWN ON THE BARREL TO ASSIST
SPADE EXTRACTION

TEST THE LIKELIHOOD OF THIS OCCURRENCE.
PROVIDE WARNINGS AND TRAINING.

PRIMER INSERTER OPERATION:

SPENT PRIMER MUST BE EXTRACTED FOR MISFIRE DIAGNOSIS
MUST HAVE A REMOVEABLE LANYARD FOR FIRING WITH A LONG
LANYARD FOR ZONE 8. IT SHOULD NOT BE POSSIBLE TO
FIRE THE GUN BY MAINTAINING TENSION ON LANYARD AS
THE BARREL RETURNS TO BATTERY.

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PROBLEM

CANNONEER NO 1 IS INJURED BY
THE BREECH CLOSING
RAM TRAY MOVEMENT
PROJECTILE RAMMER

RECOMMENDATION

CONTROLS FOR THESE FUNCTIONS SHOULD BE
ACCESSIBLE ONLY TO CANNONEER NO 1.
CONTROLS SHOULD BE LOCATED TO PREVENT
INADVERTENT ACTUATION. THE CONTROL FOR
PROJECTILE RAM SHOULD REQUIRE BOTH HANDS
FOR ACTIVATION - TWO BUTTONS LOCATED OVER
24" APART

CHARGING HIGH PRESSURE NITROGEN

REVIEW EQUIPMENT, INSTRUCTIONS AND
PROCEDURES FOR SAFETY HAZARDS

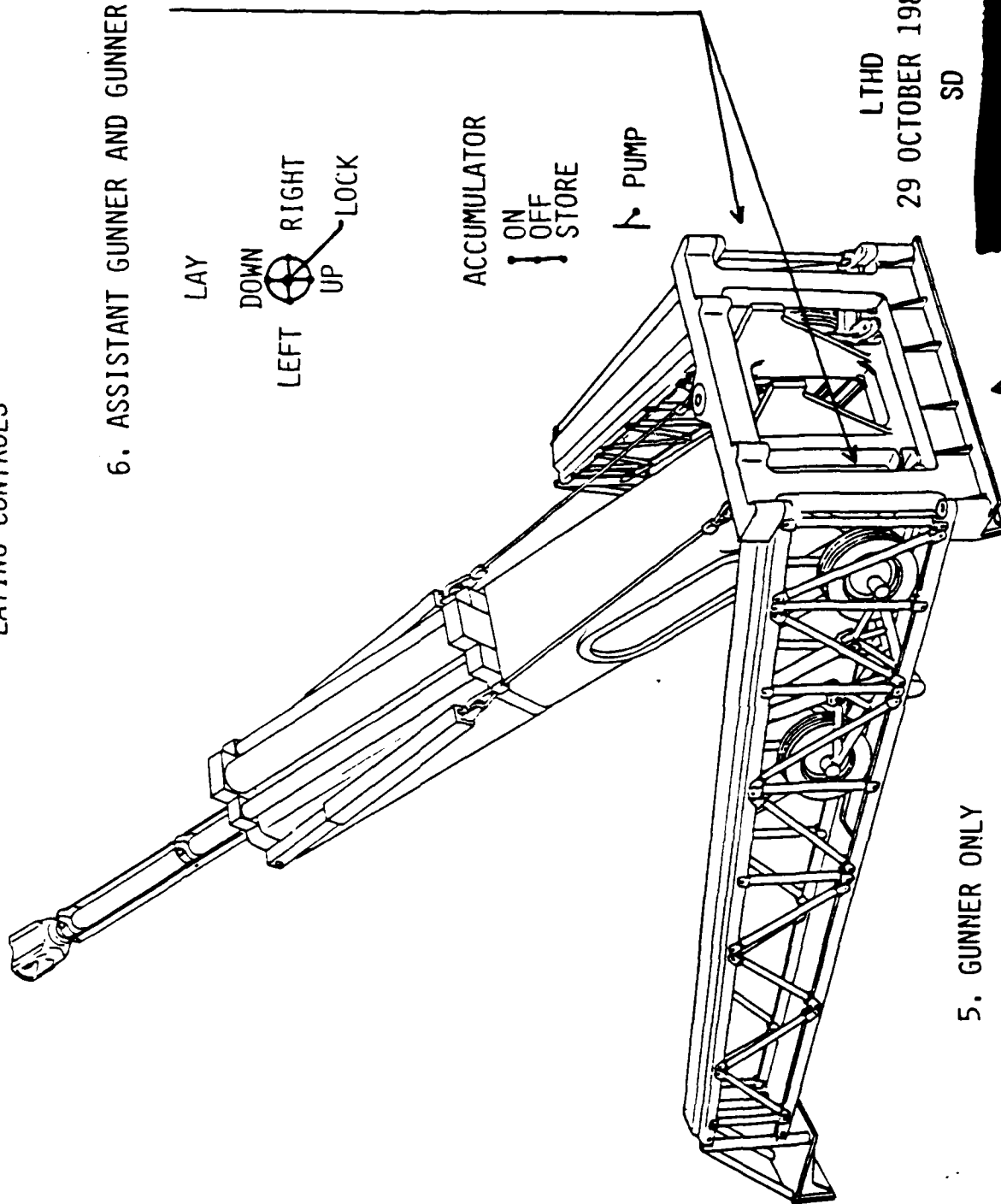
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EQ

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FMC

LAYING CONTROLS

6. ASSISTANT GUNNER AND GUNNER



5. GUNNER ONLY

⊙ ACCUMULATOR PRESSURE GAGE

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7. LOADING CONTROLS

BREECH BLOCK

! OPEN
! CLOSE

LOAD TRAY

! RAM & RETRACT
! READY

BREECH POSITION

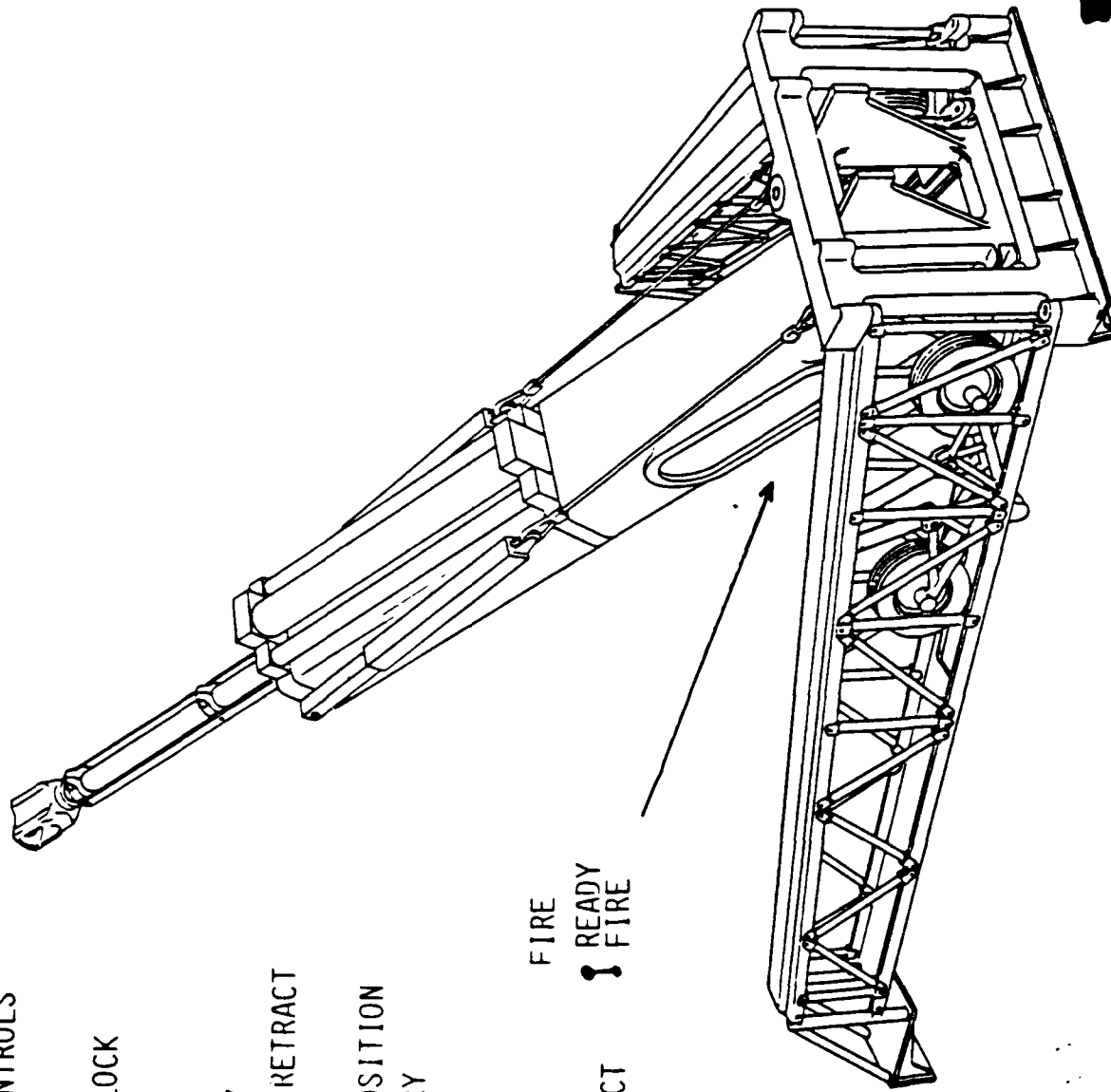
! BATTERY
! HOLD
! LOAD

PRIMER

! SET
! EXTRACT

FIRE

! READY
! FIRE



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8. EMPLACEMENT CONTROLS

CANNON POSITION

EXTEND
LOCK
RETRACT

EQUILIBRATOR CONTROL

ON
OFF

EQUILIBRATOR PRESSURE

INCREASE
HOLD
DECREASE

TEMP. GAGE

EQUILIBRATOR PRESSURE GAGE

LEFT BRAKE CONTROL

CREEP
LOCK
RELEASE

LEFT BRAKE PRESSURE GAGE

RIGHT BRAKE CONTROL

- SAME

RIGHT BRAKE PRESSURE GAGE

- SAME

11. MUZZLE BRAKE

12. PRIME MOVER
(NOT SHOWN)

10. RIGHT CLAW

3. RIGHT FRT WHL
FRT WHL CONTROL
FRT WHL POS

4. RIGHT REAR WHL
REAR WHL CONTROL
REAR WHL POS

9. LEFT CLAW

1. LEFT FRT WHL

FRT WHL CONTROL

ON
OFF

FRT WHL POS

UP
HOLD
DOWN

2. LEFT REAR WHL

REAR WHL CONTROL

ON
OFF

REAR WHL POS

UP
HOLD
DOWN

LTMD

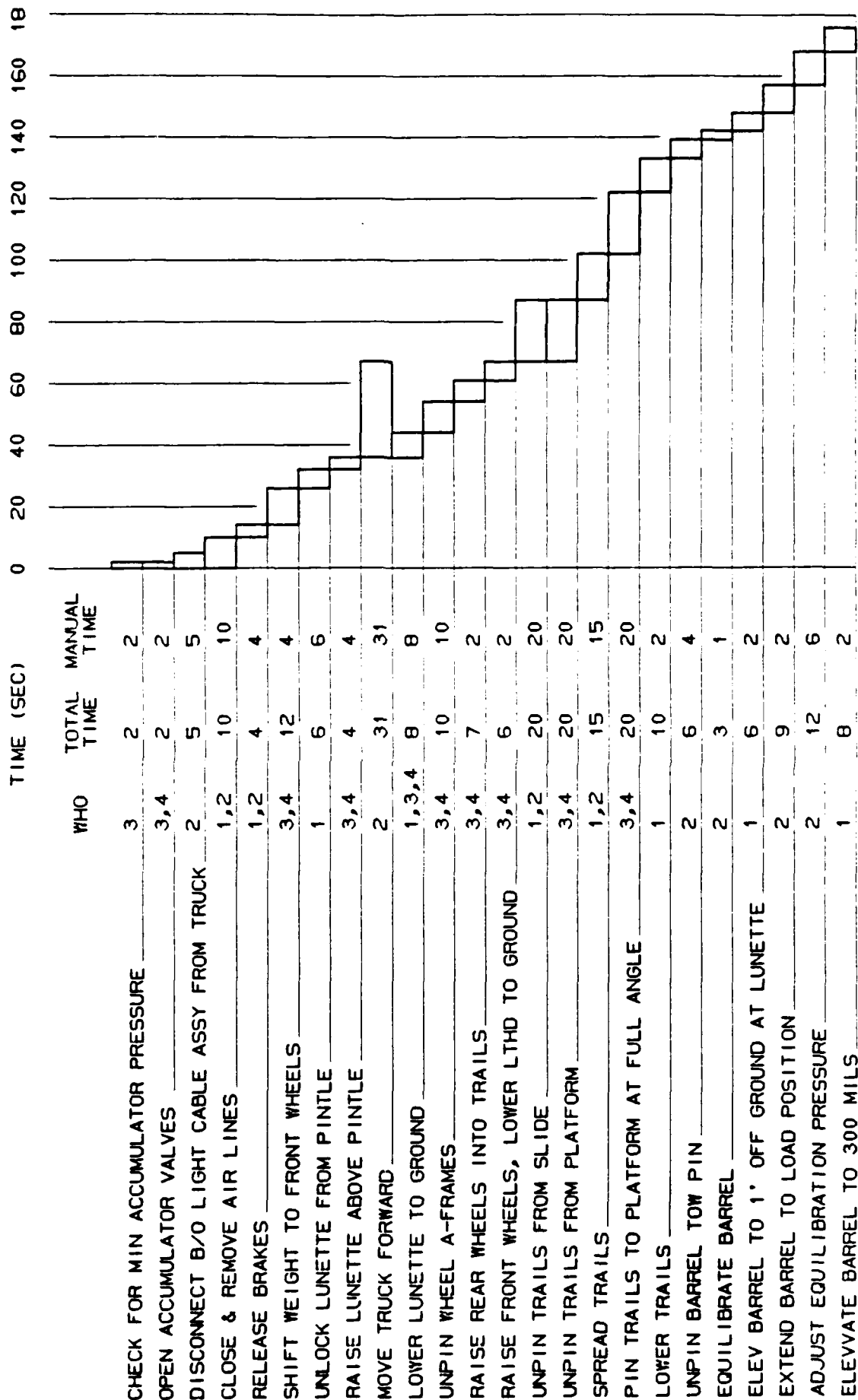
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EMPLACEMENT TIMELINE

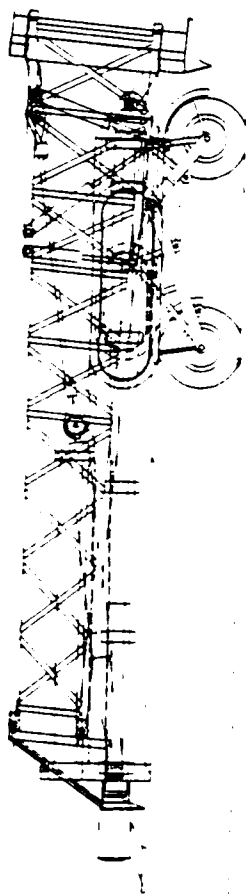


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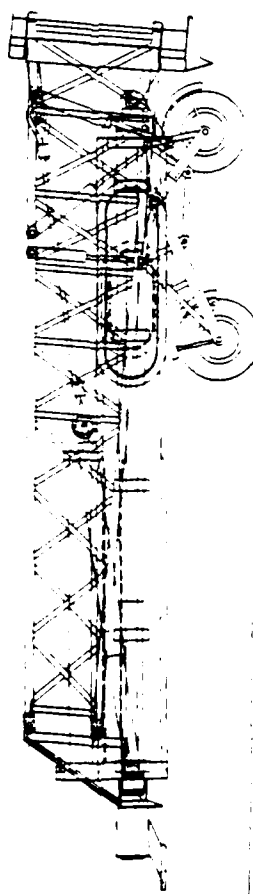
LTHD
29 OCTOBER 1986
SD

FMC LTHD EMPLACEMENT PROCEDURE

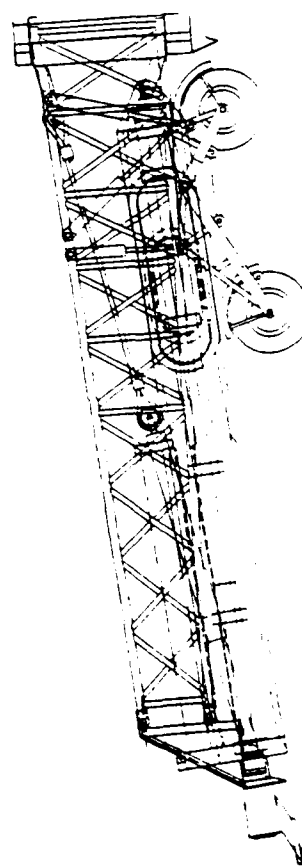
FMC



TOW POSITION



SHIFT WEIGHT TO FRONT WHLS
(LOWER FRONT WHEELS)



LOWER FRONT OF LTHD TO GROUND

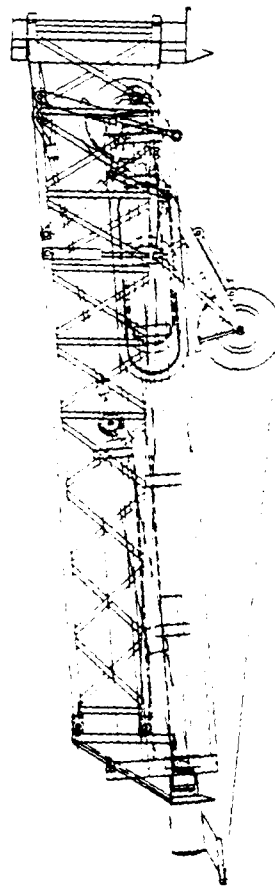
LTHD
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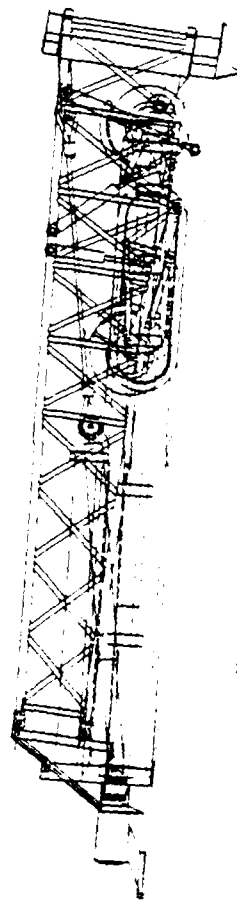
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UNPIN WHEEL FRAMES



RAISE REAR WHEELS INTO TRAILS

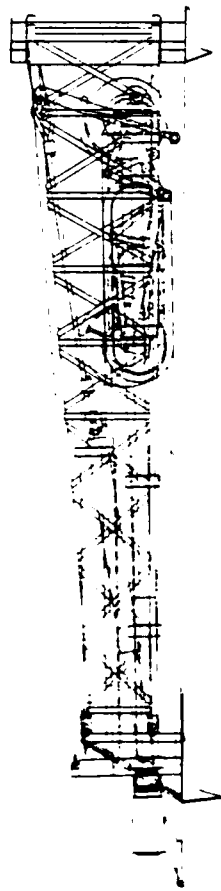


RAISE FRONT WHEELS, LOWER LTHD TO GROUND

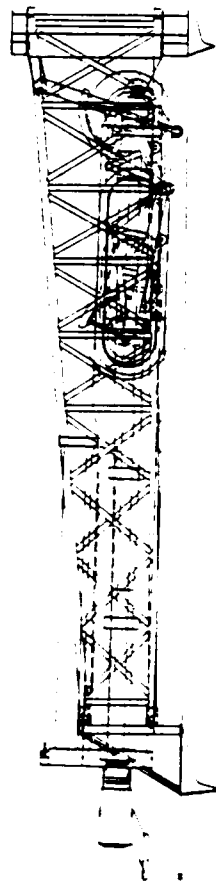
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SD TRAILS (NOT SHOWN)



LOWER TRAILS



EQUILIBRATE BARREL, ELEVATE

LTHD

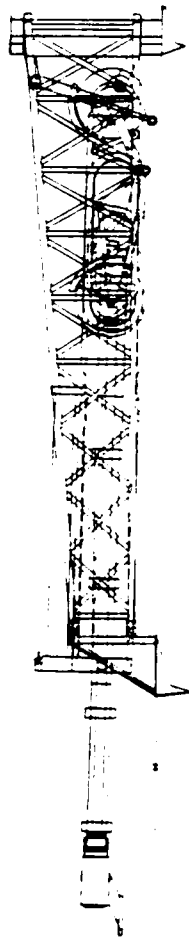
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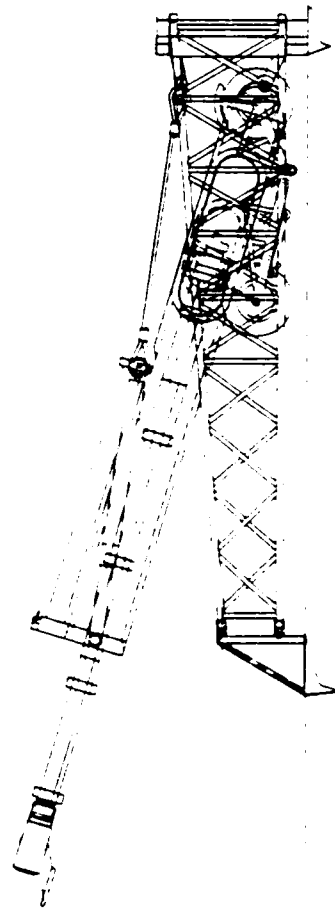
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EXTEND BARREL TO LOAD POSITION



ELEVATE BARREL

LTHD

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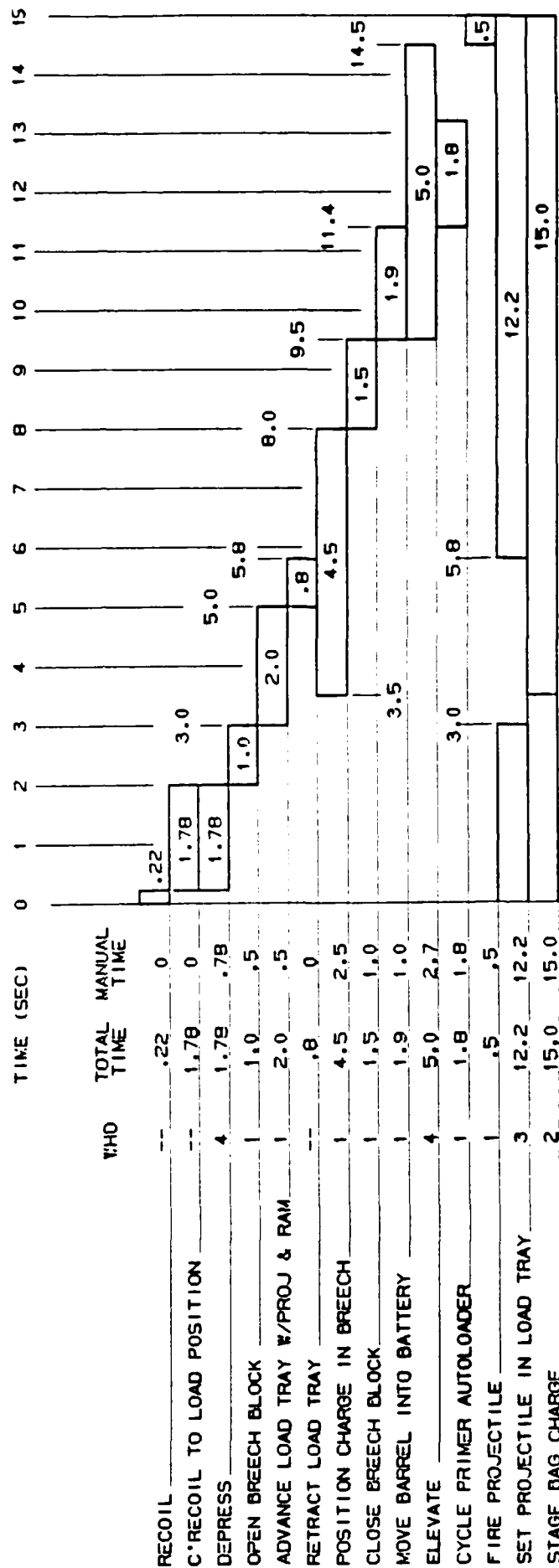
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TIME LINE FOR MAX RATE OF FIRE



3.5

LTHO
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FMC

BARREL ELEVATION/DEPRESSION TIMES (SECONDS)

	ENERGY RECOVERY	MANUAL
0 TO 72 DEGREES	6.4	39.4
72 TO 0 DEGREES	6.6	69.8

(VALUES ARE FOR REAL GAS ADIABATIC EXPANSION AND
COMPRESSION)

SYSTEM CHARACTERISTICS:

GAS: NITROGEN
EQUILIBRATED: ISOTHERMALLY
EQUILIBRATOR VOLUME = 1000 CU. IN.
PRECHARGE PRESSURE = 3000 PSI
MAX PRESSURE, 0 QE, ISOTHERMAL = 5000 PSI
MAX PRESSURE, 0 QE, ADIABATIC = 5646 PSI

LTHD

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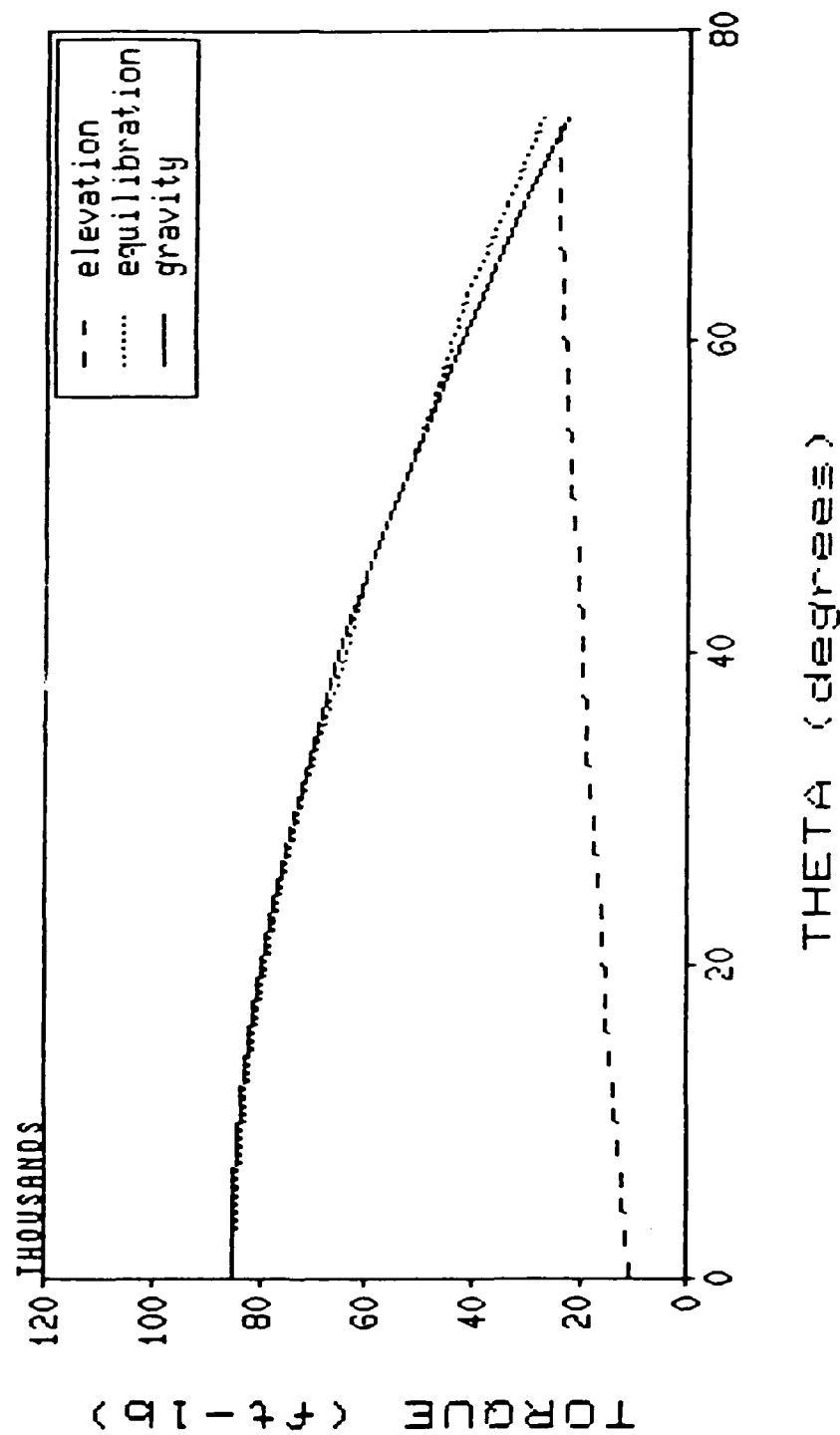
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STATIC ANALYSIS RESULTS - Nitrogen

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LTHD

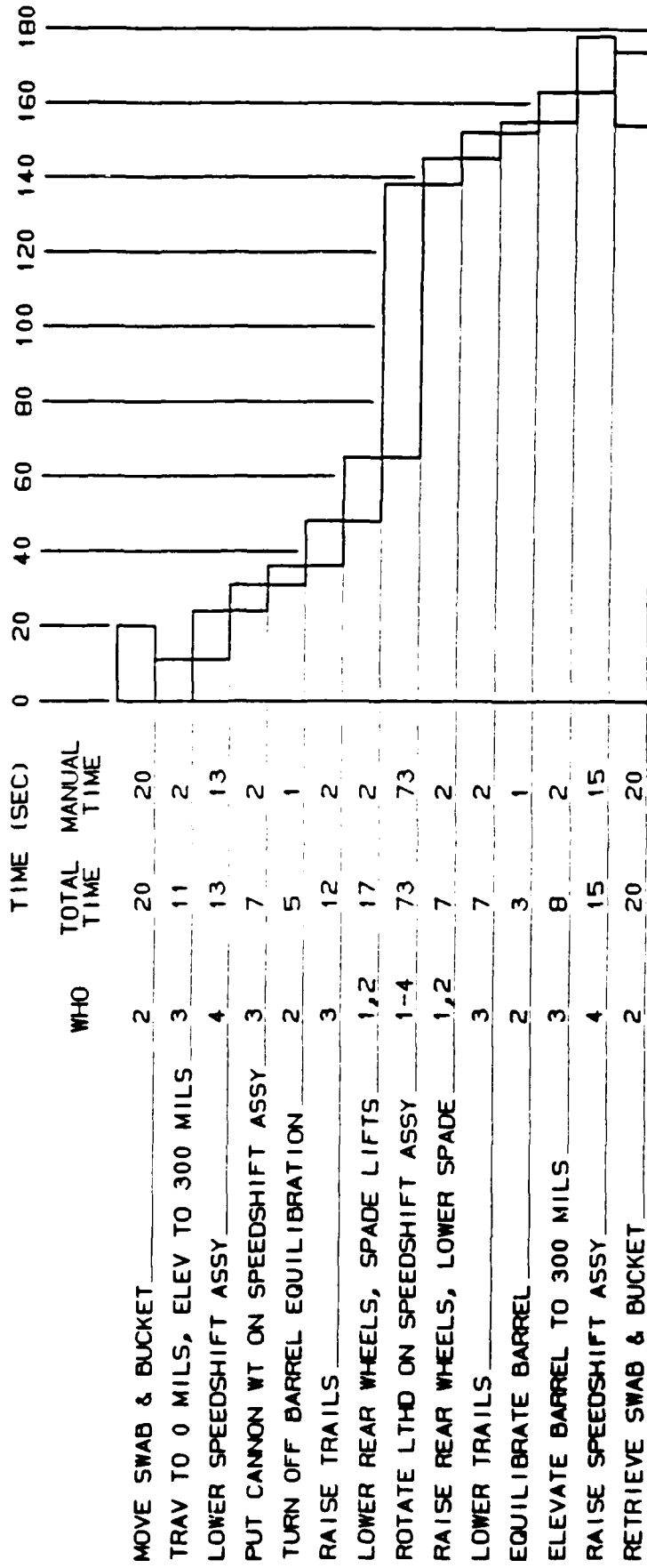
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SPEEDSHIFT TIMELINE



LTHD

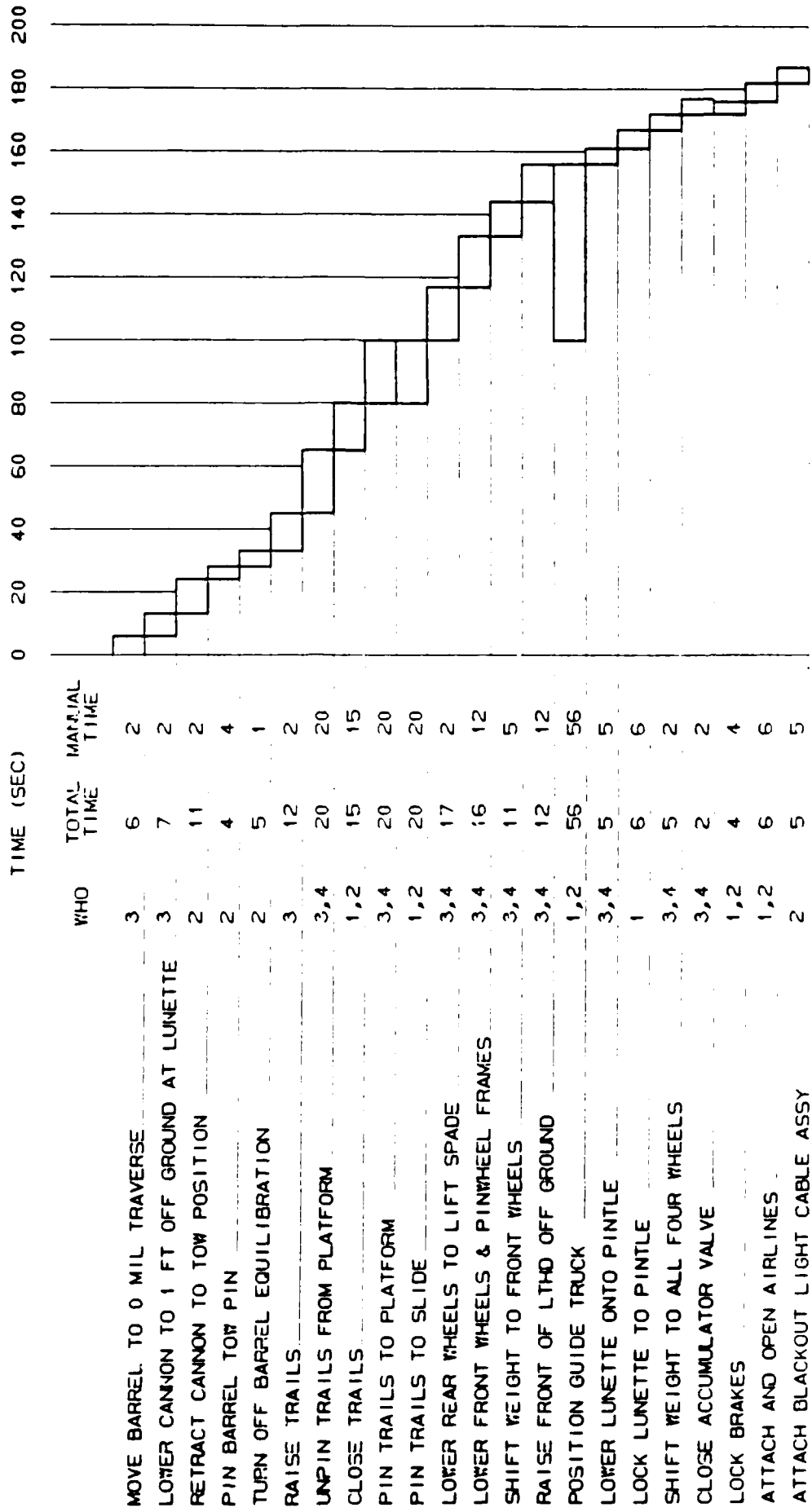
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DISPLACEMENT TIMELINE



LTHD
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FMC LTHD FIRING LOAD CONDITIONS

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION A MAXIMUM RECOIL FORCE OF 79,000 LBS AND A MAXIMUM RIFLING TORQUE OF 42,416 FT-LBS.

LTHD STRUCTURE TO WITHSTAND THE DESIGNED RECOIL FORCE-TIME PROFILE HAVING A MAXIMUM RECOIL FORCE OF 62,000 LBS AND THE DESIGNED RIFLING TORQUE-TIME PROFILE HAVING A MAXIMUM RIFLING TORQUE OF 26,000 FT-LBS.

LOADS ARE APPLIED AT ALL BARREL ORIENTATIONS, INCLUDING:

0 DEG QE, 0 DEG TRAV
0 DEG QE, 22.5 DEG TRAV
72 DEG QE, 0 DEG TRAV
72 DEG QE, 22.5 DEG TRAV

CONSTRAINTS: FIRE POSITION, WITH TWO GROUND CONDITIONS:

HARD GROUND, SPADE HOLDS 100%
SOFT GROUND, SPADE HOLDS 68%, EACH CLAW HOLDS 16%

SOURCE: 79,000 LBS - FMC ESTIMATE OF 105% PIMP CONDITION.
42,416 FT-LBS - ARDEC ESTIMATE OF 105% PIMP CONDITION.
TIME-PROFILES - FMC ESTIMATE OF DYNAMIC CONDITIONS
RESULTING FROM FIRING HOT, ZONE 8S W/ XM795 PROJECTILE.

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FMC LTHD NON-FIRING LOAD CONDITIONS

FIRE POSITION (EMPLACED)

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION THE
STATIC LOADS FROM ITS INTERNAL COMPONENTS (E.G., EQUILIBRATORS)
AT ALL BARREL ORIENTATIONS INCLUDING:

0 DEG QE, 0 DEG TRAV
0 DEG QE, 22.5 DEG TRAV
72 DEG QE, 0 DEG TRAV
72 DEG QE, 22.5 DEG TRAV

CONSTRAINTS: FIRE (OR EMPLACED) POSITION.

SOURCE: LOAD CONDITION RESULTING FROM FMC LTHD DESIGN.

LTHD

29 OCTOBER 1986

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FMC

SPEEDSHIFT

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION A 9,000 LB WEIGHT AT THE SPEEDSHIFT ASSEMBLY, ALONG WITH 500 LB HORIZONTAL FORCE INPUTS PERPENDICULAR TO THE LUNETTE, CLAWS AND PLATFORM.

CONSTRAINTS: SYSTEM WEIGHT ON SPEEDSHIFT ASSEMBLY, TRAILS SPREAD.

SOURCE: FMC ESTIMATE OF WORST-CASE LOADING CONDITION.

LTHD

29 OCTOBER 1986

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FMC

HELICOPTER TRANSPORT

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION A WORKING LOAD AT EACH SLINGING PROVISIONS EQUAL TO 3.2 TIMES ITS PROPORTIONATE SHARE OF 9,000 LBS. ULTIMATE STRENGTH OF LTHD STRUCTURE TO BE NOT LESS THAN 1.5 TIMES THE WORKING LOAD.

CONSTRAINTS: TOW POSITION, FOUR SLINGING PROVISIONS: TWO AT FORWARD MANIFOLD, TWO AT REAR PLATFORM. TRUE ANGLE OF SLING LEG MUST NOT EXCEED 45 DEGREES FROM VERTICAL. APEX TO BE ABOVE C.G. AND LESS THAN 24 FEET FROM GROUND.

SOURCE: MIL-STD-209F, 5 SEPTEMBER 1984, "SLINGING AND TIEDOWN PROVISIONS FOR LIFTING AND TYING DOWN MILITARY EQUIPMENT." CLASS I SLINGING PROVISIONS, TYPE II EQUIPMENT.

LTHD

29 OCTOBER 1986

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FMC

PRIME MOVER (TRUCK) TRANSPORT

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION AN 18,000 LB HORIZONTAL PULL AT THE LUNETTE CONCURRENT WITH THE FRONT WHEELS OF THE WALKING BEAMS HITTING ROAD OBSTACLES SUCH THAT THE REAR WHEELS START TO LIFT OFF THE GROUND.

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION A 9,000 LB HORIZONTAL PULL AT THE LUNETTE COMBINED WITH A 0.8 G LATERAL LOAD AT THE WHEELS.

CONSTRAINTS: TOW POSITION. LUNETTE LOCKED TO PRIME MOVER PINTLE.

SOURCE: FMC ESTIMATES OF WORST-CASE TOWING CONDITIONS.

LTHD

29 OCTOBER 1986

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FMC

AIRCRAFT TRANSPORT

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION 2 G'S IN THE UPWARD DIRECTION, 4.5 G'S IN THE DOWNWARD DIRECTION, 3 G'S IN THE FORWARD, 3 G'S IN REARWARD DIRECTIONS (AIR DROP), AND 1.5 G'S Laterally.

CONSTRAINTS: TOW POSITION. MINIMUM OF FOUR TIEDOWN PROVISIONS.

SOURCES: MIL-A-8421F, 25 OCTOBER 1974, "AIR TRANSPORTABILITY REQUIREMENTS, GENERAL SPECIFICATIONS FOR."

LTHD

29 OCTOBER 1986

SD

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FMC

LOW VELOCITY PARACHUTE DEPLOYMENT

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION
A LOAD OF 18.5 G'S IN THE DOWNWARD DIRECTION.

CONSTRAINTS: TOW POSITION WITH WHEELS RETRACTED. SUPPORTED AT
BOTTOM OF CRADLE, TRAILS AND PLATFORM WITH CRUSHABLE PALLET.

SOURCE: "AIR TRANSPORTABILITY CRITERIA FOR TRACKED COMBAT
VEHICLES," BY D. WILSON. FMC CORPORATION.

LTHD

29 OCTOBER 1986

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FMC

LAPES DEPLOYMENT

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION:

- A. 6 G'S IN DOWNWARD DIRECTION AT REAR OF PALLET AT 15 DEGREES TO HORIZONTAL.
- B. FOLLOWED BY 20 G'S IN DOWNWARD DIRECTION AT FRONT OF PALLET WITH PALLET HORIZONTAL.

CONSTRAINTS: TOW POSITION WITH WHEELS RETRACTED. SUPPORTED AT BOTTOM OF CRADLE, BARREL, TRAILS, AND PLATFORM WITH COLLAPSABLE PALLET.

SOURCES: "AIR TRANSPORTABILITY CRITERIA FOR TRACKED COMBAT VEHICLES," BY D. WILSON. FMC CORPORATION. CONVERSATIONS WITH D. WILSON.

LTHD

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RAIL TRANSPORT LOADS

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION 15 G'S FORWARD AND BACKWARD.

LTHD STRUCTURE TO WITHSTAND WITHOUT PERMANENT DEFORMATION LOADS AT EACH TIEDOWN PROVISION EQUAL TO: 4.0 TIMES ITS PROPORTIONATE SHARE OF 9,000 IN THE FORWARD AND BACKWARD DIRECTIONS, 2.0 TIMES ITS PROPORTIONATE SHARE IN THE UPWARD DIRECTION AND 1.5 TIMES ITS PROPORTIONATE SHARE IN THE LATERAL DIRECTION. LOADS APPLIED STATICALLY AND INDEPENDENTLY AT SYSTEM C.G.

ULTIMATE STRENGTH OF LTHD TIEDOWN PROVISIONS AND STRUCTURAL FRAME TO BE NOT LESS THAN 1.5 TIMES THE YIELD STRENGTH.

CONSTRAINTS: TOW POSITION, WHEELS BLOCKED, MIN. OF FOUR TIEDOWN PROVISIONS. (ALTERNATIVE: WHEELS RAISED INTO TRAILS, 4+ TIEDOWNS.)

SOURCES: FMC ESTIMATE OF G-LOADING TO BE EXPERIENCED IN RAIL CAR IMPACT TEST. (MIL-STD-810D, 19 JULY 1983, METHOD 516.3, SHOCK, PROCEDURE VIII - RAIL IMPACT.)

MIL-STD-209F, 5 SEPTEMBER 1984, "SLINGING AND TIEDOWN PROVISIONS FOR LIFTING AND TYING DOWN MILITARY EQUIPMENT." CLASS II TIEDOWN PROVISIONS.

LTHD

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HARDWARE

1. INTEGRATION/ASSEMBLY
2. CANNON
 - 2A. BARREL AND BREECH
 - 2B. YOKE-WAY-BAND ASSEMBLY
 - 2C. MUZZLE BRAKE
 - 2D. PRIMER AUTO LOADER AND LINKAGE
3. CARRIAGE
 - 3A. RECOIL/ENERGY RECOVERY SYSTEM
 - 3B. CRADLE
 - 3C. GIMBAL
 - 3D. PLATFORM
 - 3E. SPADE
 - 3F. TRAILS
 - 3G. CLAW
 - 3H. LOADING SYSTEM
 - 3I. EMPLACEMENT CONTROLS
 - 3J. WHEEL AND BRAKE SYSTEM
 - 3K. MISCELLANEOUS CARRIAGE ITEMS
4. FIRE CONTROL
 - 4A. MEASUREMENT
 - 4B. TUBE LAY

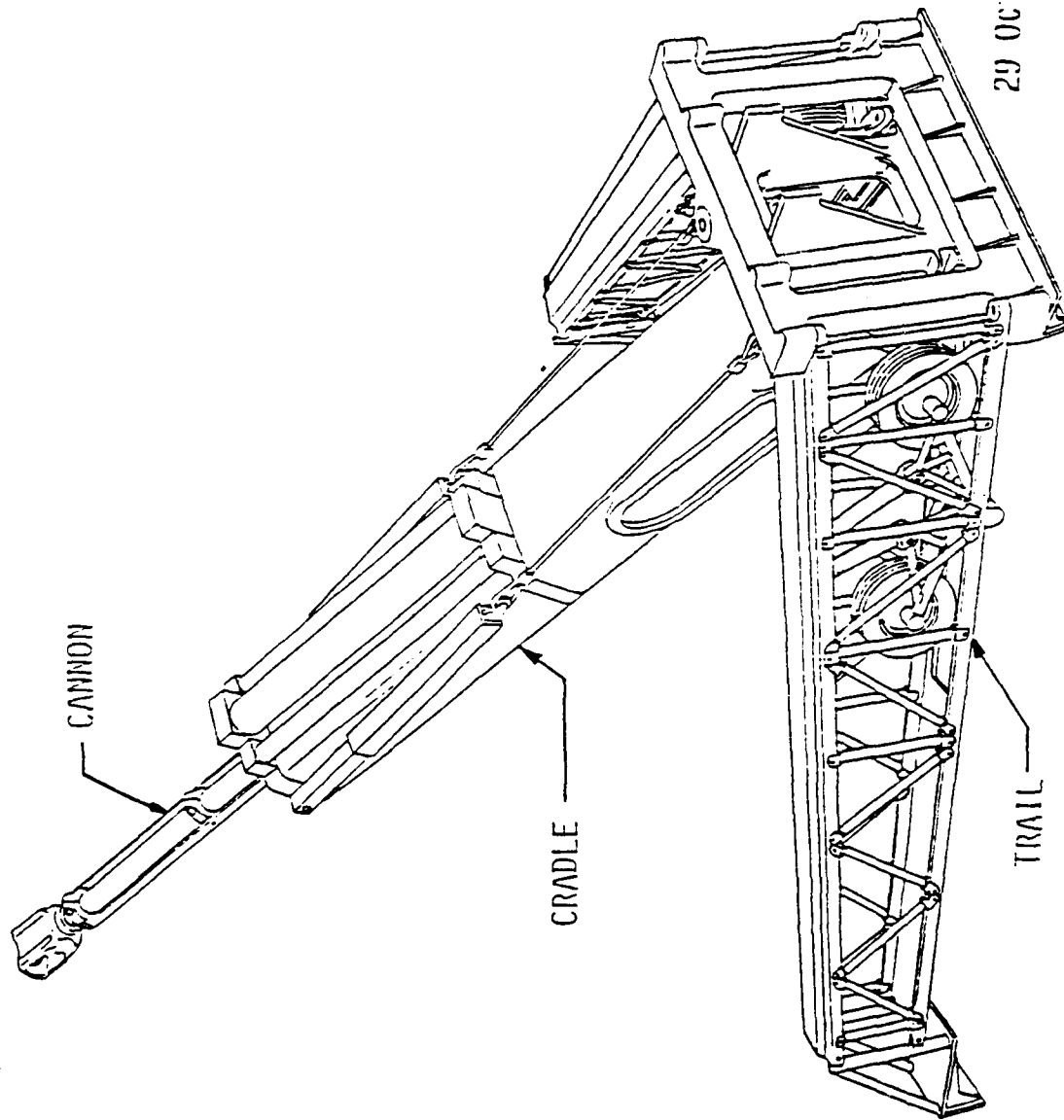
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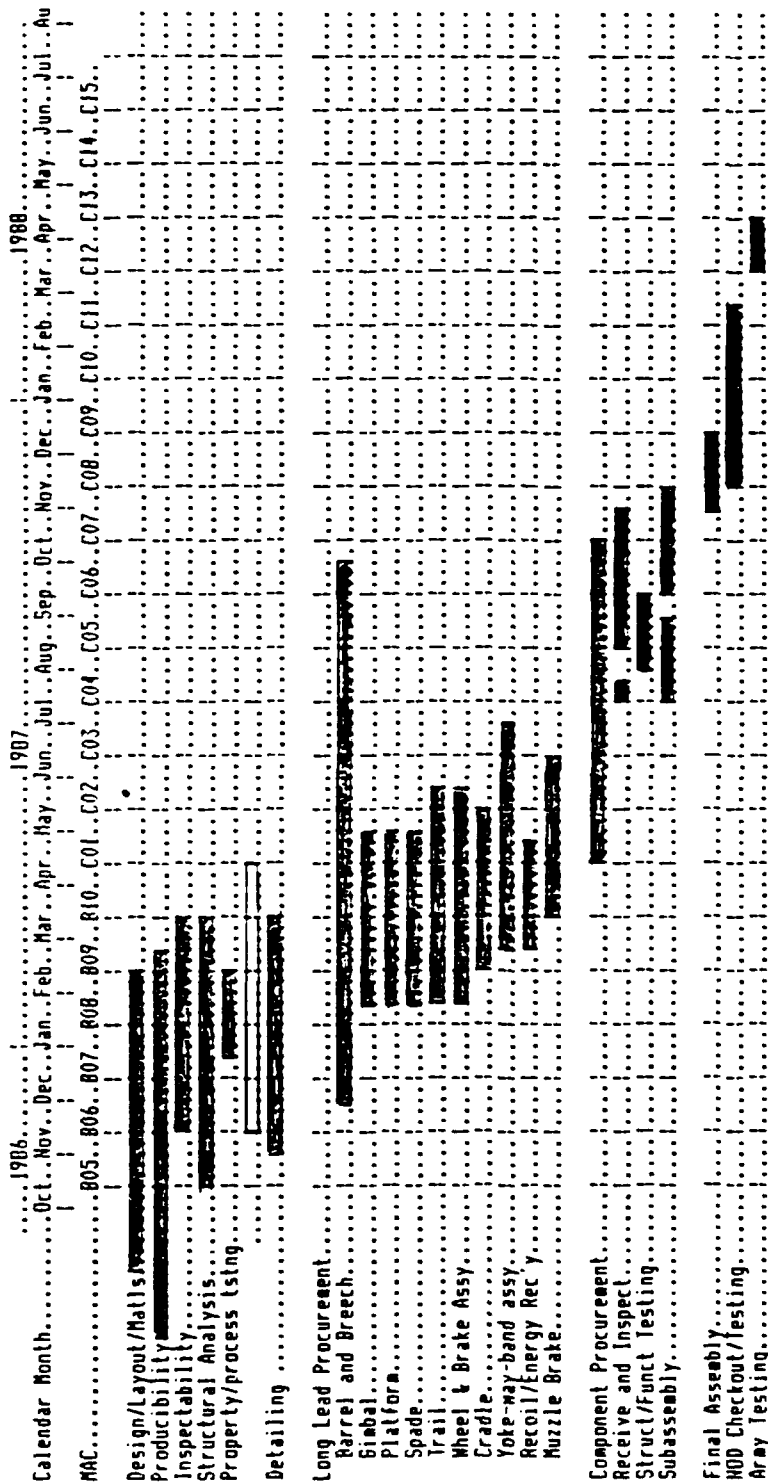
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LTID AGGREGATE GANTT CHART



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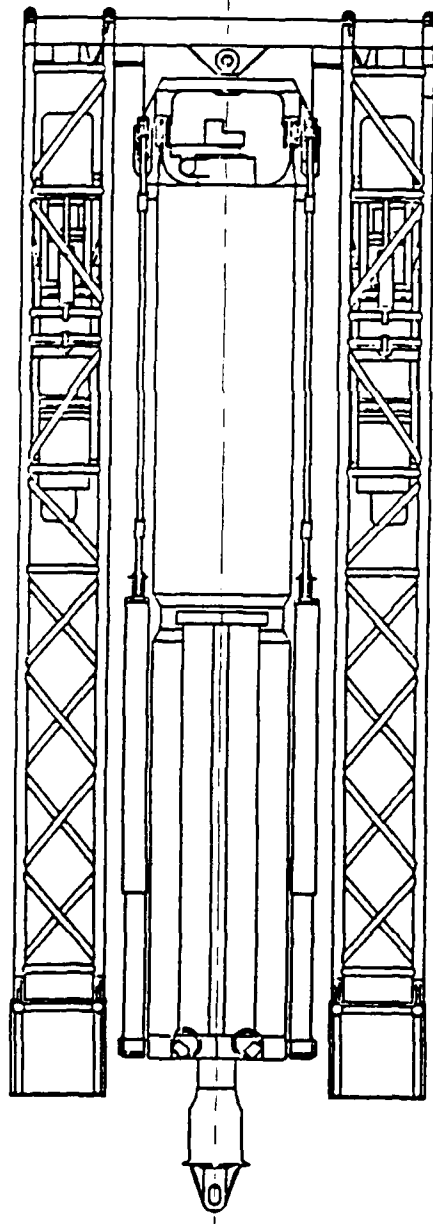
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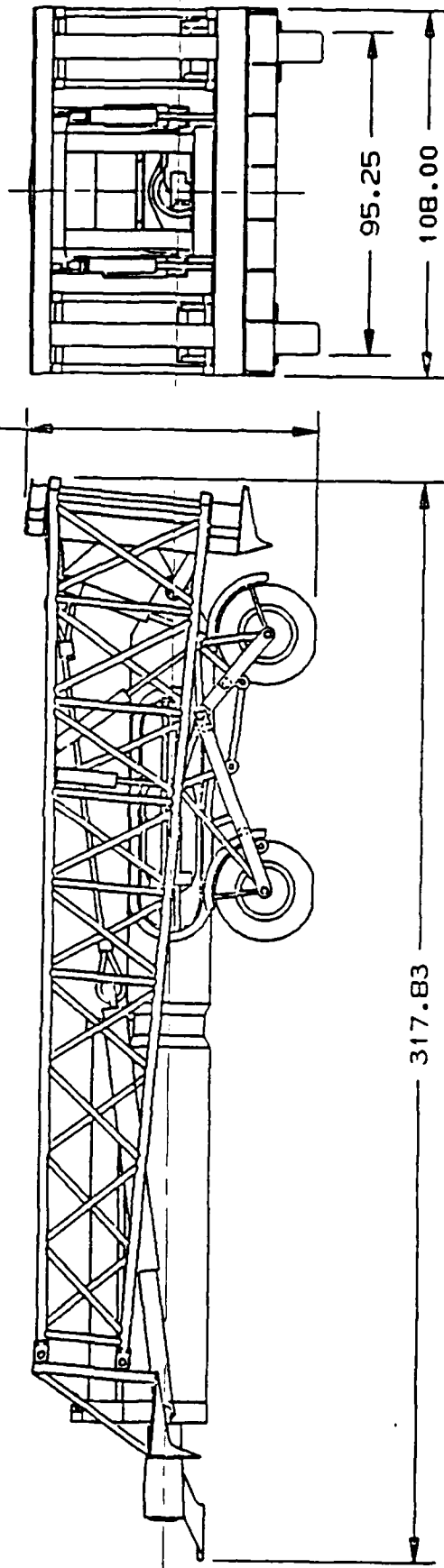
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INTERGRATION/ASSY



86.15



6'

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29 OCTOBER 1986
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INTEGRATION/ASSEMBLY

Item.....
Weight (lbm).....
9054

Configuration Considerations..

WEIGHT
STABILITY (FIRING AND TRANSPORTATION)
OPERABILITY

SIMPLICITY
COST
LEAD TIME

Primary Material(s).....

TITANIUM
AL/SIC
CARBON FIBER/EPOXY

ALUMINUM
STEEL

Long Lead Items.....

Primary Vendor(s).....
NOD

Calendar Month.....	1986												1987												1988																
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.		
MAC.....	B05.	B06.	B07.	B08.	B09.	B10.	C01.	C02.	C03.	C04.	C05.	C06.	C07.	C08.	C09.	C10.	C11.	C12.	C13.	C14.	C15.																				
Design/Layout/Matls.....																																									
Productibility.....																																									
Inspectability.....																																									
Structural Analysis.....																																									
Property/process tstg.....																																									
Detailing.....																																									
Long Lead Procurement.....																																									
Component Procurement.....																																									
Receive and Inspect.....																																									
Struct/Funct Testing.....																																									
Subassembly.....																																									
Final Assembly.....																																									
MOD Checkout/Testing.....																																									
Array testing.....																																									

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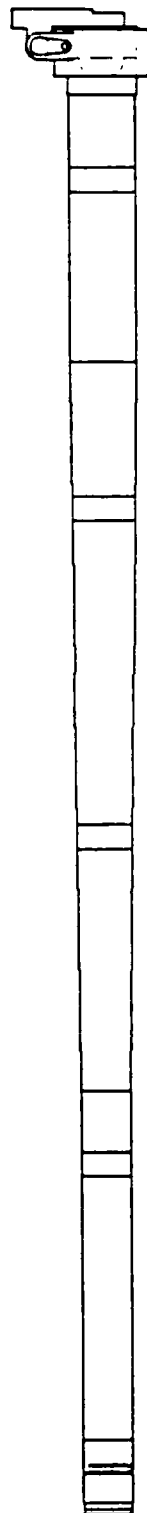
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BARREL & BREECH

XM-284 BREECH WITH BELL CRANK
BREECH OPENER (INSTEAD OF HANDLE)



XM-284 TAPERED BARREL WITH
5 YOKE MOUNTING DIAMETERS

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BARREL AND BREECH

Item.....

Weight (lbm)..... 2650 + 495 = 3145

Configuration Considerations... WEIGHT

Primary Material(s)..... STEEL

Long Lead Items..... BARREL

WATERVLIET VIA ARDEC

Primary Vendor(s).....

Calendar Month.....	1986												1987												1988																	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
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Productibility.....																																										
Inspectability.....																																										
Structural Analysis.....																																										
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Final Assembly.....																																										
MOD Checkout/Testing.....																																										
Array Testing.....																																										

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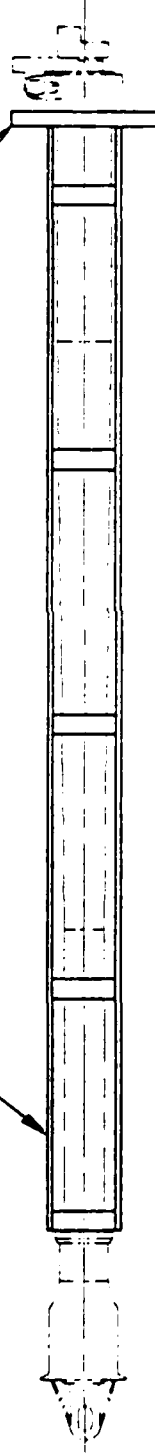
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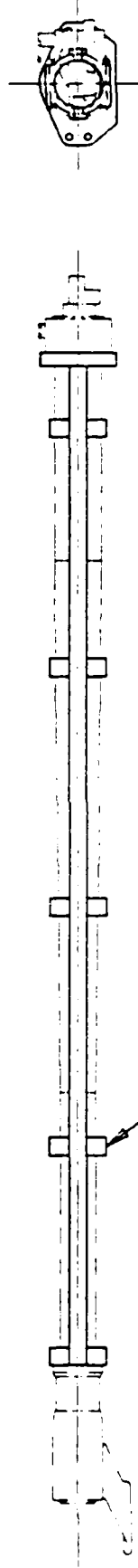
YOKE-WAY-BAND ASSY

1" X 5" AL/SIC WAYS

TITANIUM BAND
(KEYED TO BREECH & BARREL)



(5) 4" WIDE AL/SIC YOKES
(KEYED TO BARREL)



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BA

FMC

YOKE-WAY-BAND-ASSEMBLY

Item.....

Weight (lbm).....

Configuration Considerations..

WEIGHT
LOAD PATHS (FIRING AND LAPSE
HEAT REMOVAL FROM BARREL
DIMENSIONAL STABILITY

Primary Material(s).....

Al/SIC (2124-T6-30%)
TITANIUM

Long Lead Items.....

FORGING DIES FOR YOKES

Primary Vendor(s).....

DWA ... NOD

Calendar Month.....	1986												1987												1988																	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
MAC.....	B05..	B06..	B07..	B08..	B09..	B10..	C01..	C02..	C03..	C04..	C05..	C06..	C07..	C08..	C09..	C10..	C11..	C12..	C13..	C14..	C15..																					
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Final Assembly.....																																										
MOD Checkout/Testing.....																																										
Array Testing.....																																										

...Funded under Contract

☐...Generic Data Acquisition not funded under Contract

LTHD

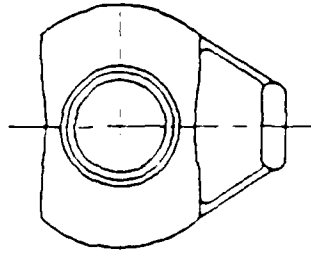
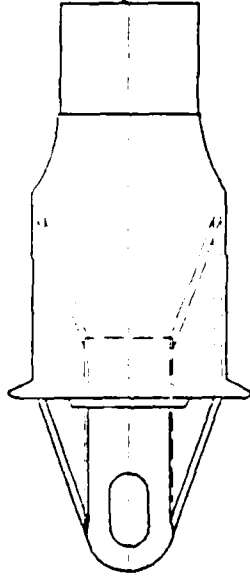
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MUZZLE BRAKE

M198 THREAD



COPY OF M198 MUZZLE BRAKE
STRENGTHENED ON NON-AIRFLOW
SURFACES TO ACCOMMODATE
SLIGHT REDUCTION IN MATERIAL
PROPERTIES (TITANIUM VS STEEL)

ADDITION OF LUNETTE

67

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MUZZLE BRAKE

TOWING LOAD PATH
WEIGHT
M198 BLAST FIELD

TITANIUM

PATTERN EQUIPMENT

TITECH ... NOD

[illegible]

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89 Q117

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13A

NO-A183 984

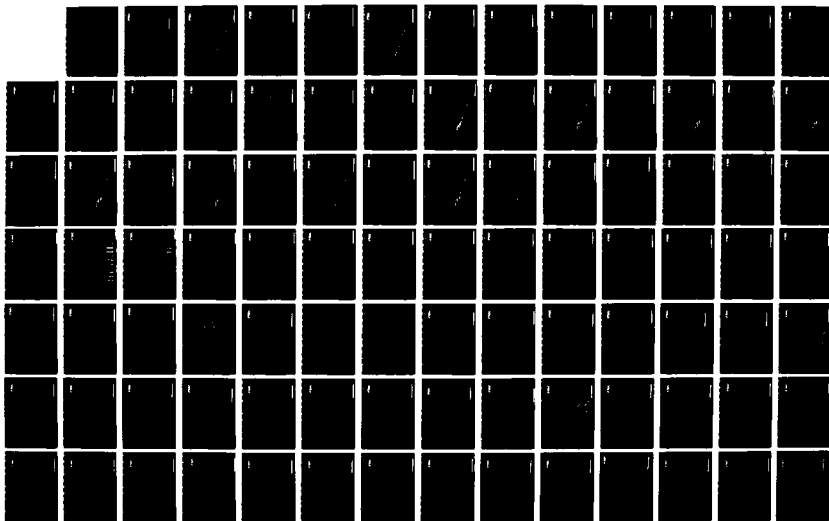
LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87
FMC-E-3041-VOL-B-PT-2 DAAA21-86-C-0047

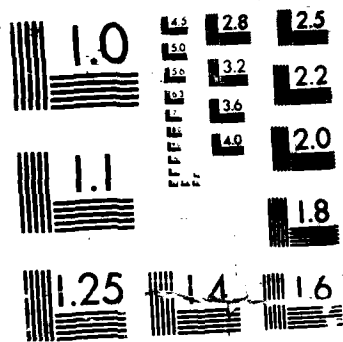
2/4

UNCLASSIFIED

F/G 19/6

NL

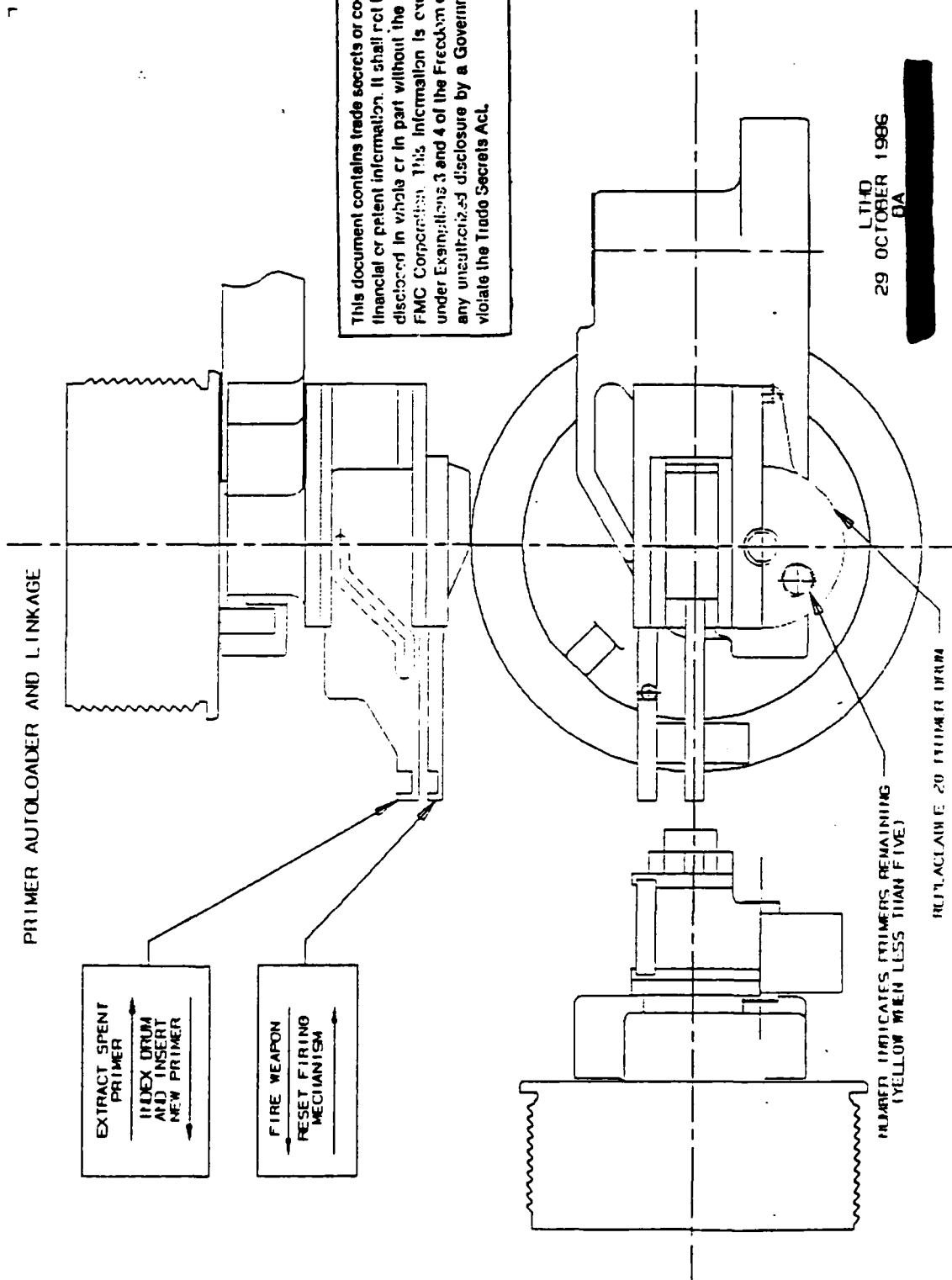




MICROCOPY RESOLUTION TEST CHART

FMC

7



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DA



PRIMER AUTO LOADER INTEGRATION

Item.....
Weight (lbm).....

30

Configuration Considerations..

ACHIEVING 4 ROUNDS PER MINUTE.
DELAY OF PRIMER INSERTION UNTIL READY TO FIRE.
SAFE HANDLING OF MISFIRES UP TO MAX QE.

Primary Material(s).....

STEEL
ALUMINUM

Long Lead Items.....

NOD

Primary Vendor(s).....

Calendar Month	1986	1987	1988
	Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug..Sep..Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Au		
MAC	805..806..807..808..809..810..C01..C02..C03..C04..C05..C06..C07..C08..C09..C10..C11..C12..C13..C14..C15..		
Design/Layout/Matls.			
Productivity			
Inspectability			
Structural Analysis			
Property/process tstng.			
Detailing			
Long Lead Procurement			
Component Procurement			
Receive and Inspect.			
Struct/Funct Testing			
Subassembly			
Final Assembly			
MDD Checkout/Testing			
Array Testing			

.....Funded under Contract ☐ ..Generic Data Acquisition not funded under Contract

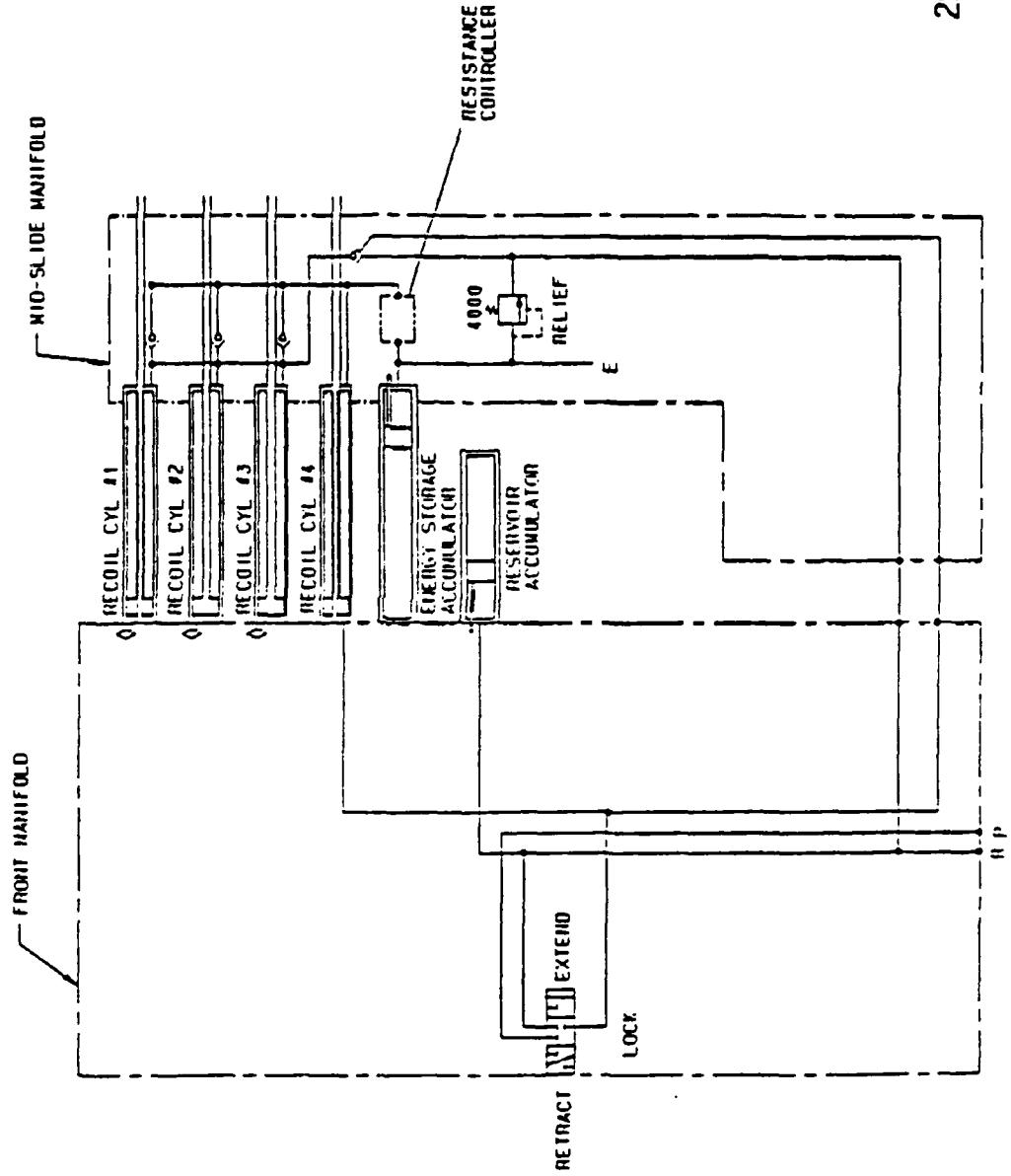
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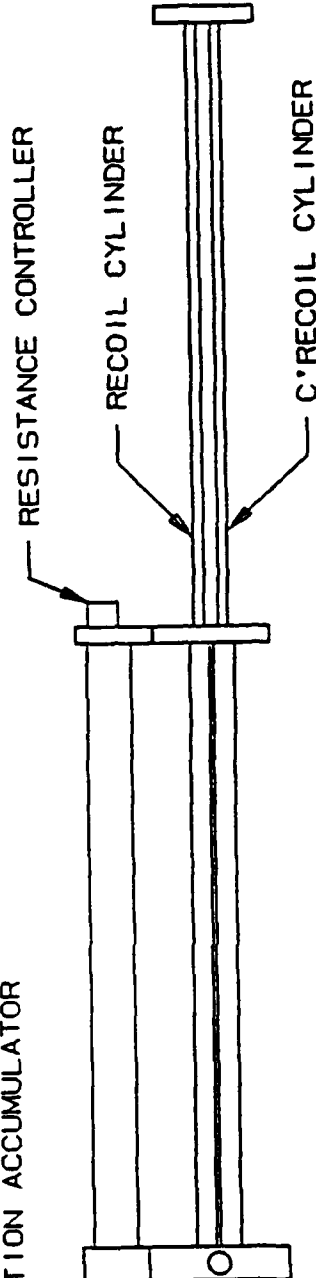
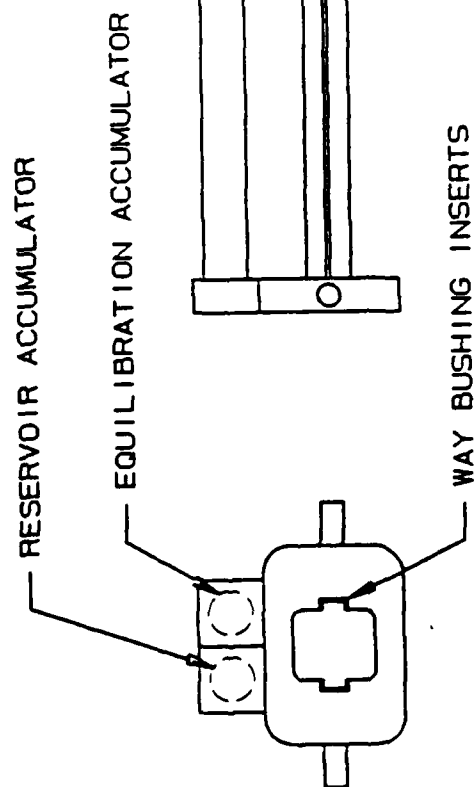
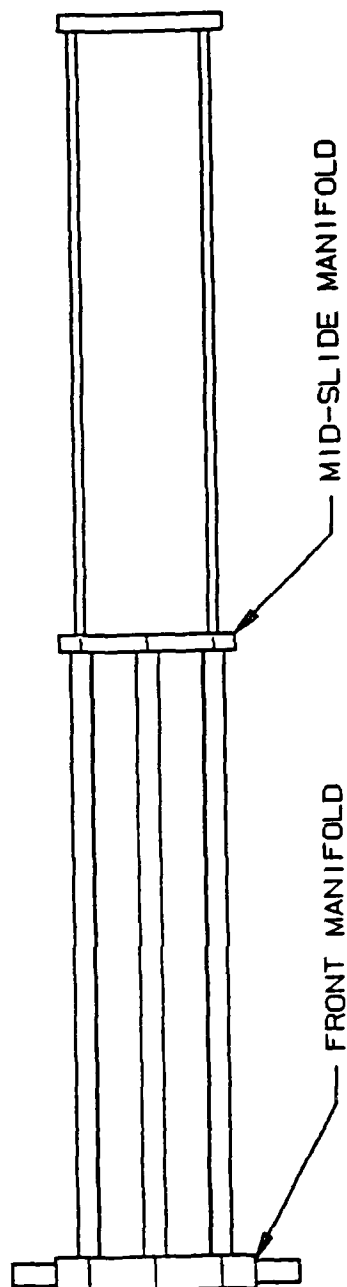
RECOIL/ENERGY RECOVERY SYSTEM



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RECOIL/ENERGY RECOVERY SYSTEM



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BA



RECOIL/ENERGY RECOVERY SYSTEM

Item.....

Weight (lbm).....

894

Configuration Considerations..

WEIGHT
ENERGY RECOVERY WITH ZONE 3
ROD PULL CURVE FLEXIBILITY
RAM-D

Primary Material(s).....

A1/SIC (2124-T6-30%) CYLINDERS
KEVLAR-WRAPPED STEEL ACCUMULATORS
2024-T6 MANIFOLDS WITH INSULATING BSG MOUNTS

Long Lead Items.....

EXTRUSION DIES AND EXTRUSIONS

Primary Vendor(s).....

NOD ... DWA ... YORK ... MAROTTA

Calendar Month.....	1986	1987	1988
	Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug..Sep..Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug		
MAC.....	B05..B06..B07..B08..B09..B10..C01..C02..C03..C04..C05..C06..C07..C08..C09..C10..C11..C12..C13..C14..C15..		
Design/Layout/Natls.			
Productibility			
Inspectability			
Structural Analysis			
Property/process tstg			
Detailing			
Long Lead Procurement			
Component Procurement			
Receive and Inspect			
Struct/Funct Testing			
Subassembly			
Final Assembly			
MOB Checkout/Testing			
Army Testing			

.....Funded under Contract

☐ ..Generic Data Acquisition not funded under Contract

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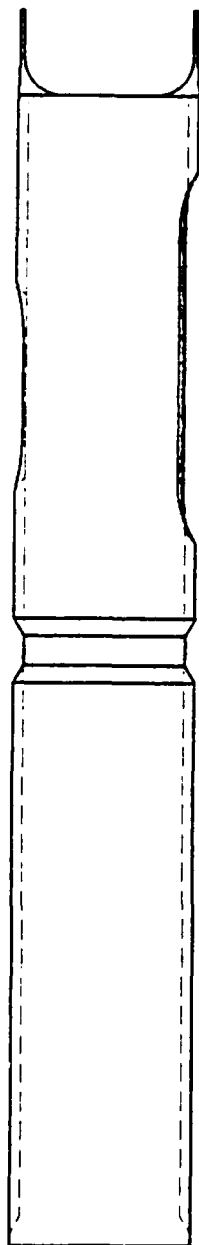
29 OCTOBER 1986

BA

73

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CRADLE



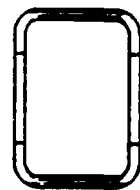
PRIMER AJT./LOADER RELOAD PORTHOLE

FRONT-SLIDE MANIFOLD MOUNT

LOADING PORTHOLE

MID-SLIDE MANIFOLD MOUNT

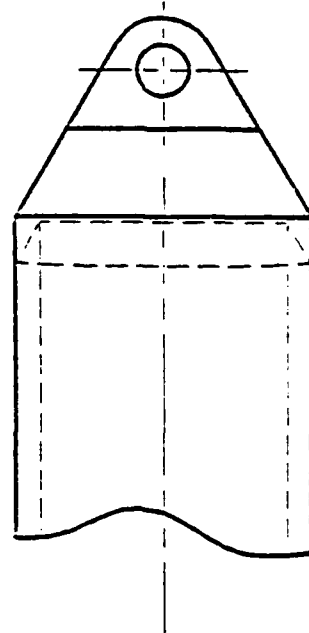
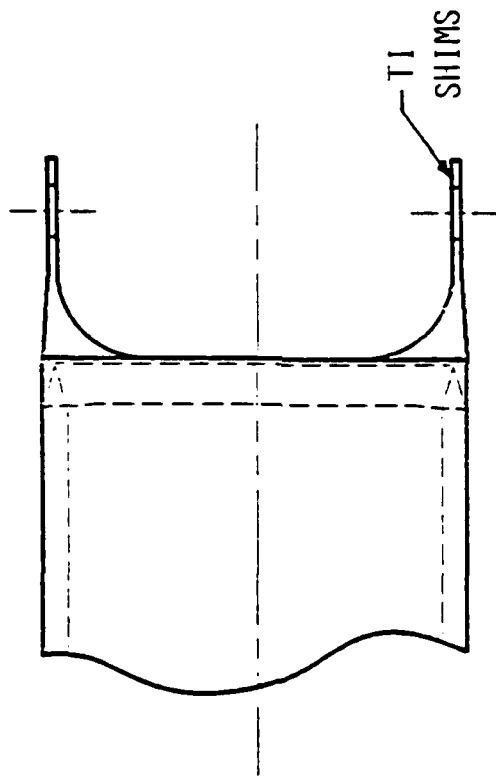
TRUNNION



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29 OCTOBER 1986

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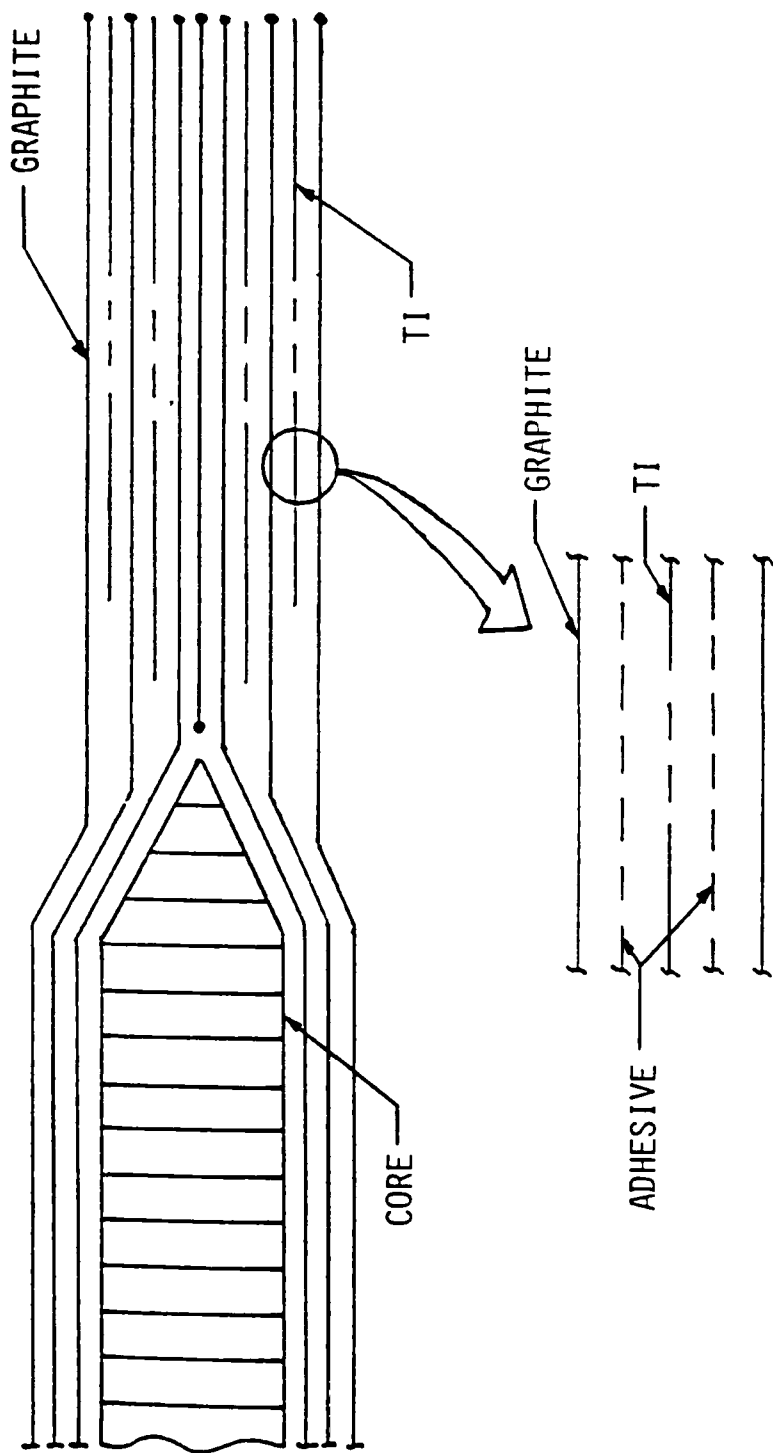
TRUNNION



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29 OCTOBER 1986
TR

FIMC

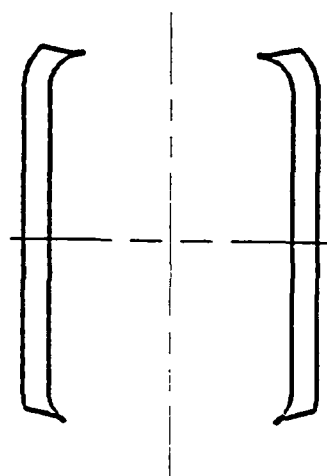
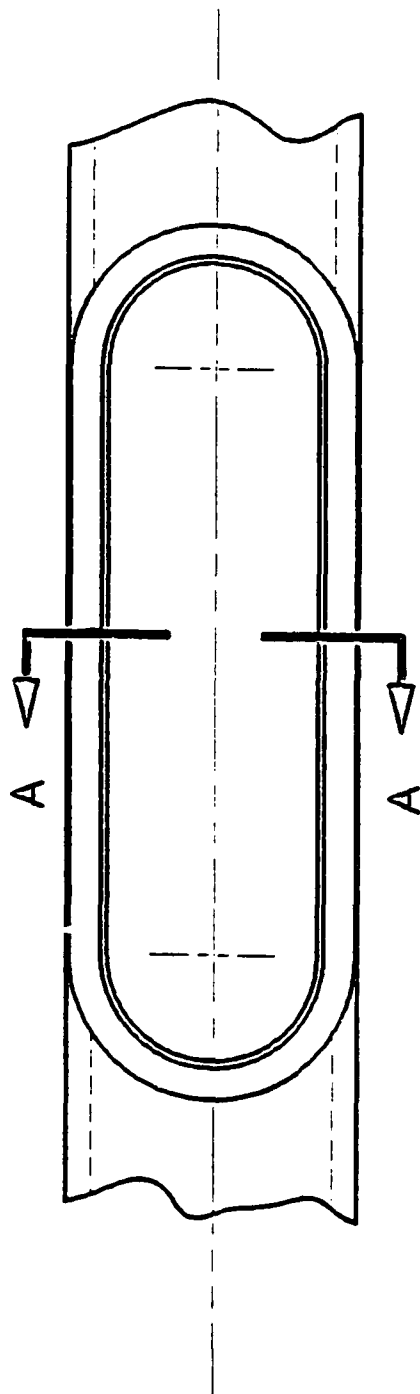
LUG DETAIL



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29 OCTOBER 1986
TR

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ACCESS HOLES

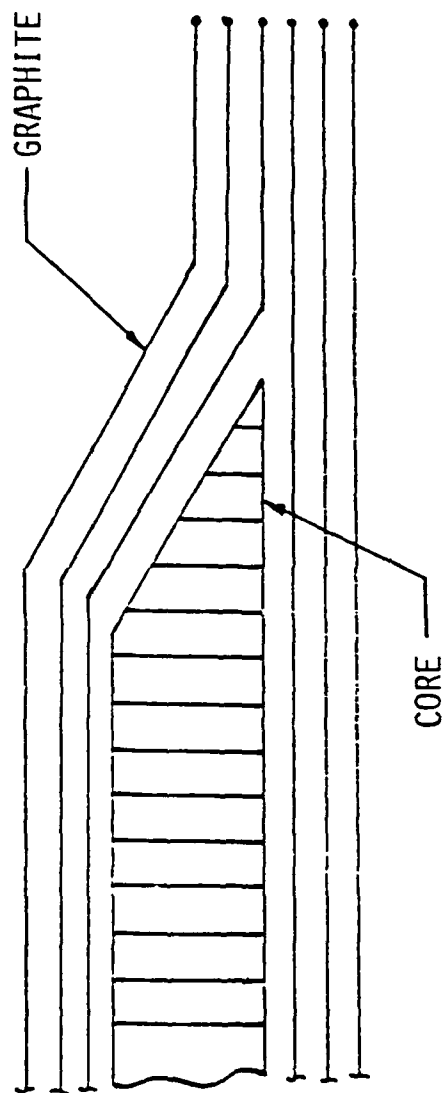


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SECTION A-A

FMC

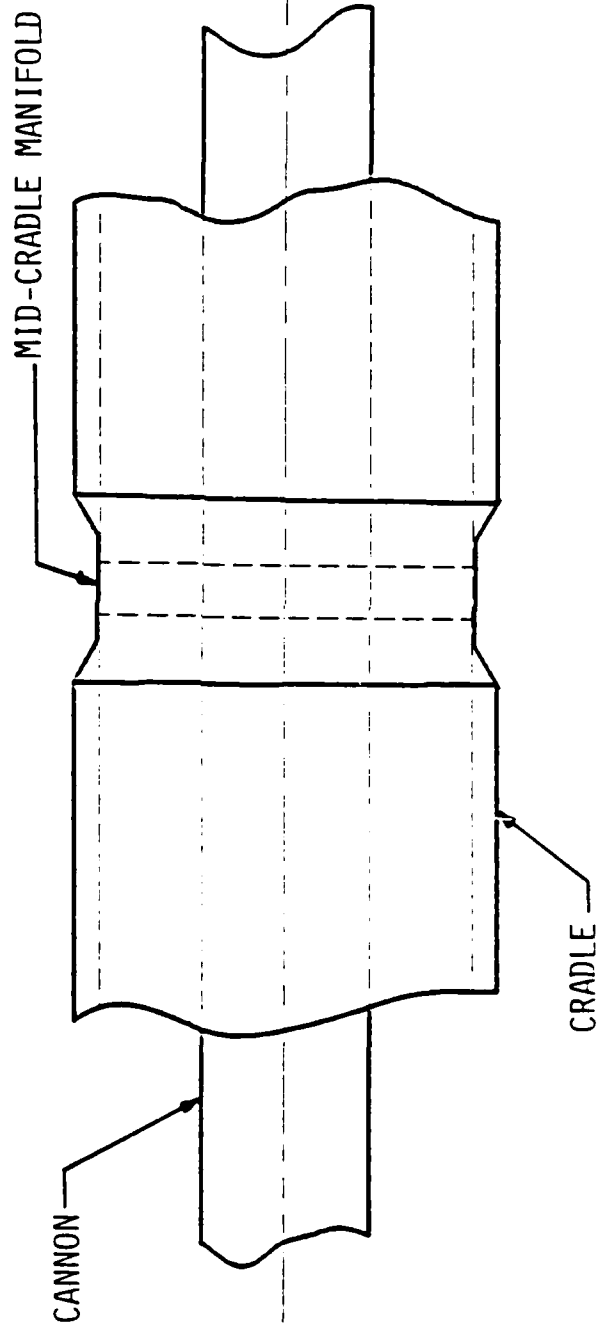
EDGE DETAIL



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MID-CRADLE MANIFOLD



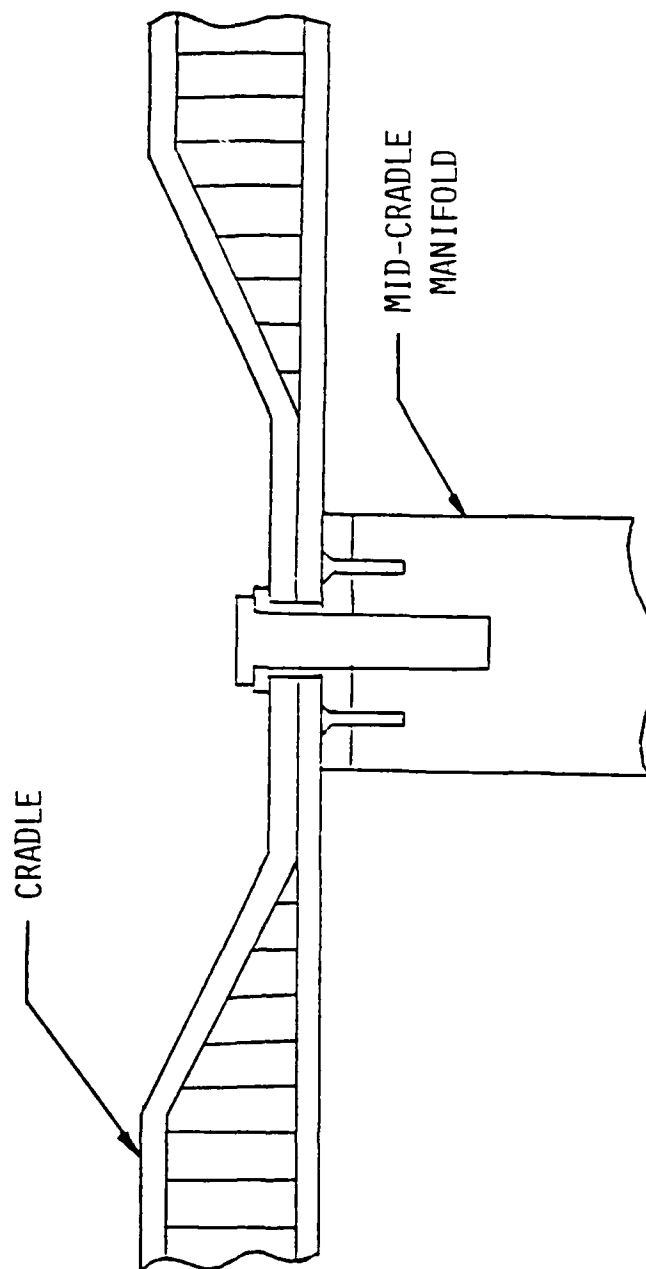
LTID

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[REDACTED]

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GRAPHITE EPOXY PROPERTIES

HERCULES AS4/3501 UNIDIRECTIONAL TAPE

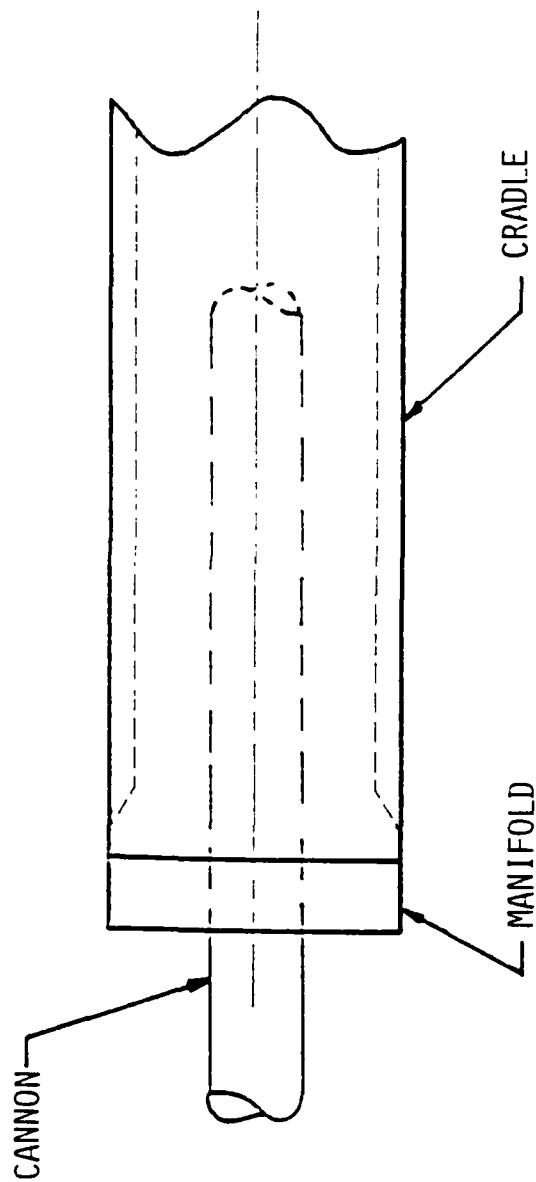
170°F/WET DATA

0°	TENSILE STRENGTH	315 KSI
0°	TENSILE MODULUS	21000 KSI
90°	TENSILE STRENGTH	3.1 KSI
90°	TENSILE MODULUS	1300 KSI
0°	COMPRESSIVE STRENGTH	158 KSI
0°	COMPRESSIVE MODULUS	20000 KSI
	SHEAR STRENGTH	12 KSI
0°	POISSONS RATIO	.30 KSI

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MANIFOLD



LHID
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COMPOSITE MATERIAL TESTING

- LOW TEMP/HIGH TEMP/HIGH HUMIDITY
TENSILE, COMPRESSIVE & SHEAR TESTING

- PIN HOLE JOINT TEST

- HIGH TEMP/HIGH HUMIDITY DOUBLE CAP
SHEAR STRENGTH TEST

- HIGH TEMP/HIGH HUMIDITY PEEL STRENGTH TEST

- CHEMICAL RESISTANCE TESTING

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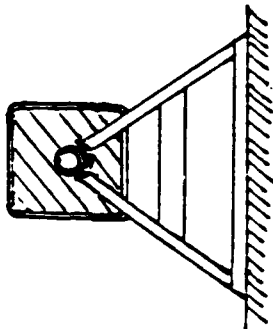
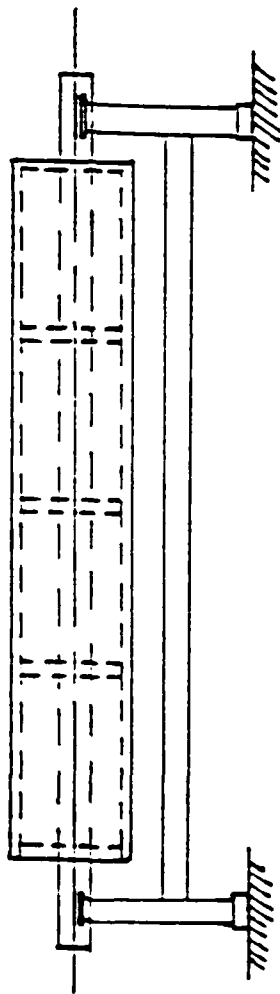
DESIGN SUPPORT

- PHASE I ANALYSIS
- COMPCAL LAMINATE ANALYSIS
- FEA IN PROGRESS

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TOOLING

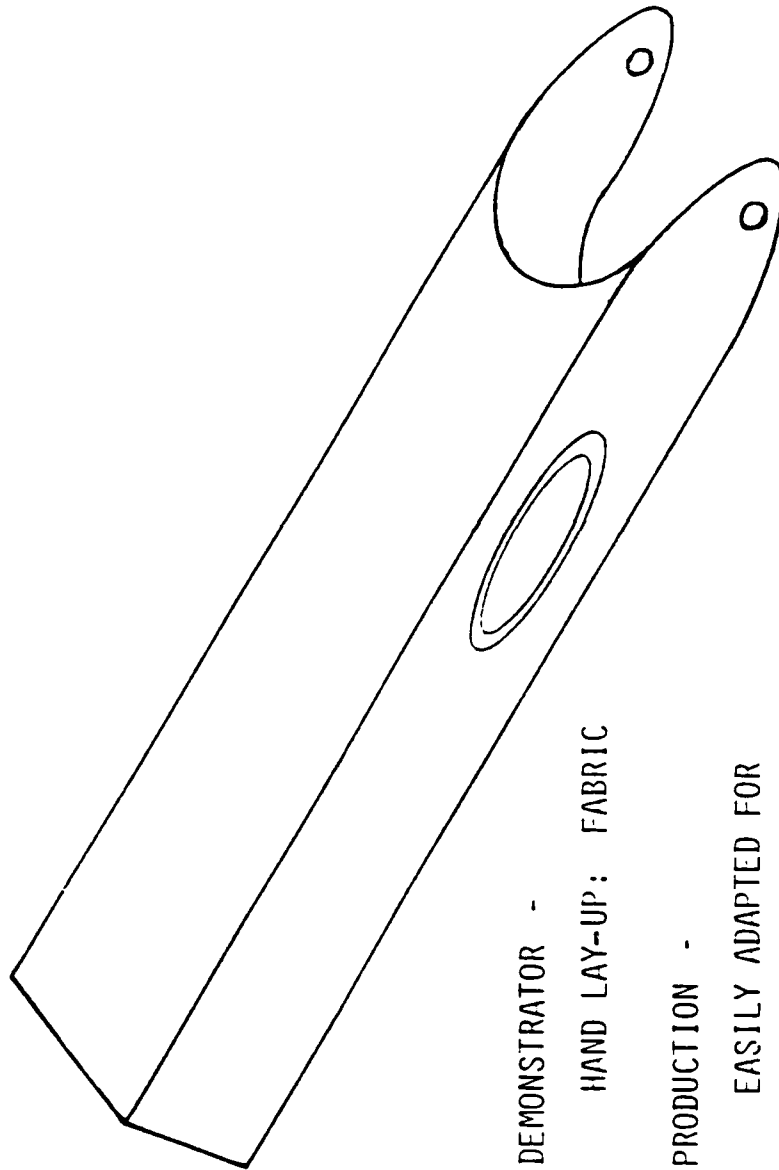


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MANUFACTURING



- DEMONSTRATOR -
HAND LAY-UP: FABRIC
- PRODUCTION -
EASILY ADAPTED FOR
FILAMENT WINDING

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CONCLUSION

- BASIC COMPOSITE DESIGN PRINCIPLES
- KEEP DETAIL AREAS SIMPLE
- KEEP TOOLING SIMPLE
- * EFFICIENT, COST EFFECTIVE PART

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CRADLE

Item.....
Weight (lbm).....

432

Configuration Considerations..
WEIGHT
COST
STIFFNESS
BREECH ACCESS
DIMENSIONAL STABILITY

Primary Material(s).....
CARBON FIBER/EPOXY
ALUMINUM AND/OR TITANIUM BUSHINGS

Long Lead Items.....
PREPREG TAPE
FASTENERS
TBD

MANDREL

Calendar Month.....	1986	1987	1988
	Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug..Sep..Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Au		
MAC.....	B05..B06..B07..B08..B09..B10..C01..C02..C03..C04..C05..C06..C07..C08..C09..C10..C11..C12..C13..C14..C15..		
Design/Layout/Matls.....			
Productibility.....			
Inspectability.....			
Structural Analysis.....			
Property/process testg.....			
Detailing.....			
Long Lead Procurement.....			
Component Procurement.....			
Receive and Inspect.....			
Struct/funct testing.....			
Subassembly.....			
Final Assembly.....			
MOB Checkout/testing.....			
Array testing.....			

☐...Funded under Contract ☐...Generic Data Acquisition not funded under Contract

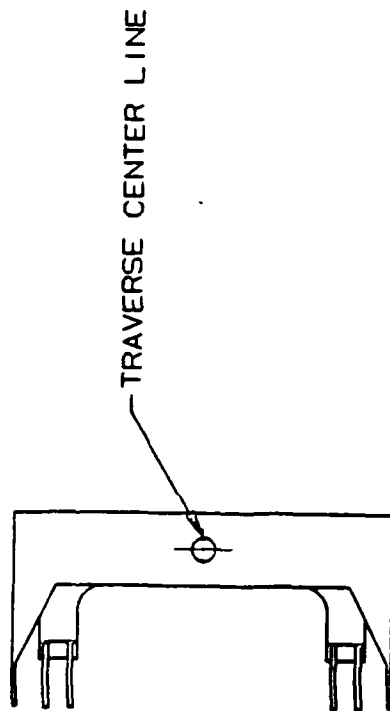
LTHD

29 OCTOBER -1986

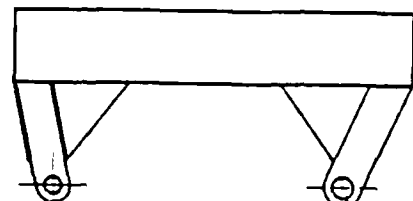
BA

FMC

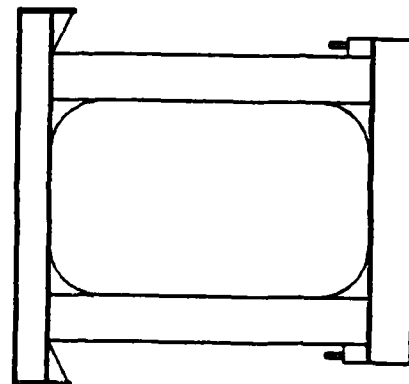
GIMBAL



EQUILIBRATION CABLE
AND ELEVATION CYL
ATTACHMENT



TRUNNION CENTER LINE



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GIMBAL

Item.....
Weight (lbm).....

225

Configuration Considerations..
WEIGHT
LOAD PATHS (FIRING)
DIMENSIONAL STABILITY
DURABILITY

Primary Material(s).....

TITANIUM

Long Lead Items.....

FIXTURES

Primary Vendor(s).....

NOD

Calendar Month	1986	1987	1988
	Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug..Sep..Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug		
MAC	805..806..807..808..809..810..C01..C02..C03..C04..C05..C06..C07..C08..C09..C10..C11..C12..C13..C14..C15..		
Design/Layout/Matls.			
Productibility			
Inspectability			
Structural Analysis			
Property/process tstg.			
Detailing			
Long Lead Procurement			
Component Procurement			
Receive and Inspect			
Struct/Funct Testing			
Subassembly			
Final Assembly			
MOD Checkout/Testing			
Army Testing			

☐...Funded under Contract ☐...Generic Data Acquisition not funded under Contract

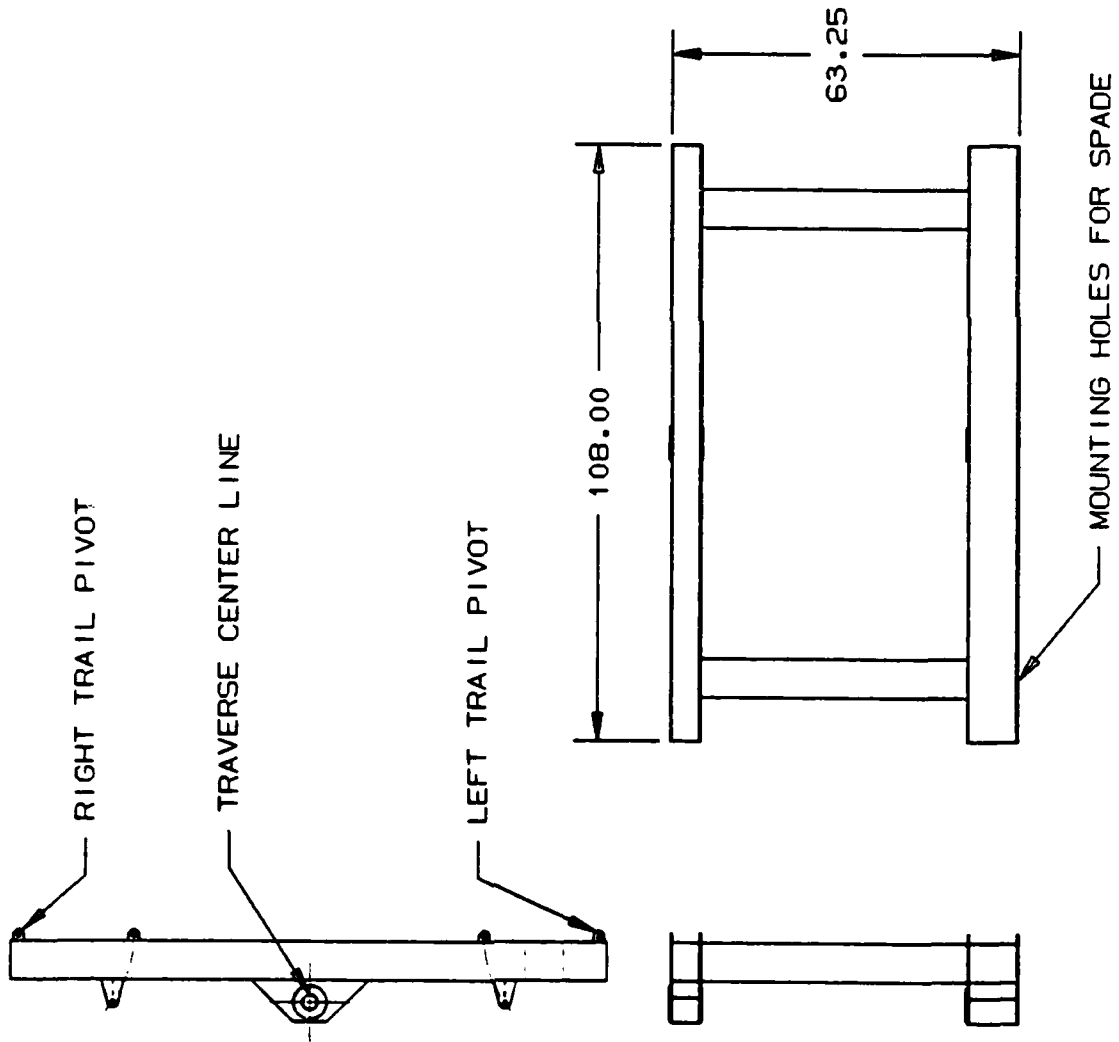
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29 OCTOBER 1986

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PLATFORM



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29 OCTOBER 1986
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PLATFORM

Item.....
Weight (lbm).....

445

Configuration Considerations...
WEIGHT
LOAD PATH
DURABILITY
COST

Primary Material(s).....
TITANIUM

Long Lead Items.....
FIXTURES

Primary Vendor(s).....
NOD

Calendar Month.....	1986												1987												1988																
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
MAC.....	B05	B06	B07	B08	B09	B10	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15																				
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Subassembly.....																																									
Final Assembly.....																																									
MOD Checkout/Testing.....																																									
Army Testing.....																																									

.....Funded under Contract

☐...Generic Data Acquisition not funded under Contract

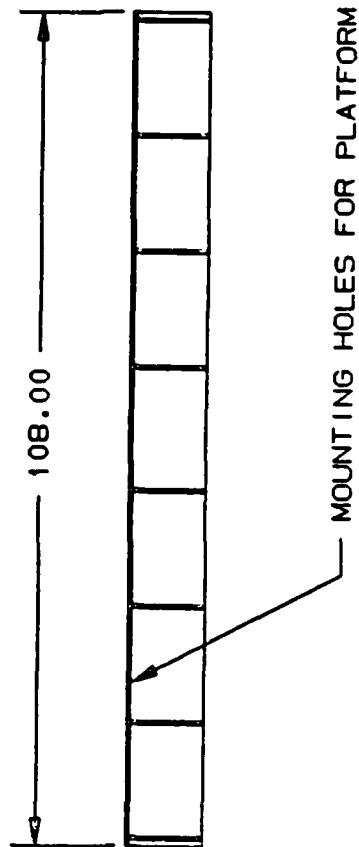
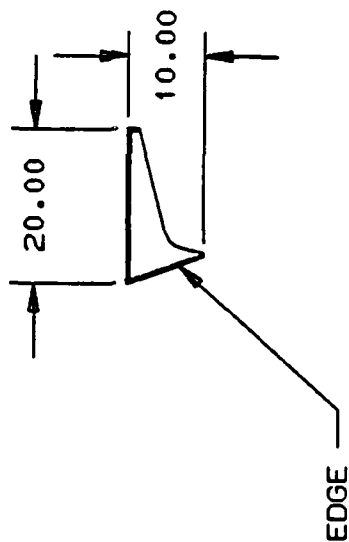
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SPADE



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29 OCTOBER 1986
BA

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SPADE

Item.....
Weight (lbm)..... 201

Configuration Considerations..
WEIGHT
DURABILITY
ANGLE OF DEPARTURE

Primary Material(s)..... TITANIUM

Long Lead Items..... FIXTURES

Primary Vendor(s)..... NOD

Calendar Month.....	1986	1987	1988
	Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug..Sep..Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug		
MAC.....	B05..B06..B07..B08..B09..B10..C01..C02..C03..C04..C05..C06..C07..C08..C09..C10..C11..C12..C13..C14..C15..		
Design/Layout/Matls.....			
Productibility.....			
Inspectability.....			
Structural Analysis.....			
Property/process tsg.....			
Detailing.....			
Long Lead Procurement.....			
Component Procurement.....			
Receive and Inspect.....			
Struct/Funct Testing.....			
Subassembly.....			
Final Assembly.....			
MOD Checkout/Testing.....			
Array Testing.....			

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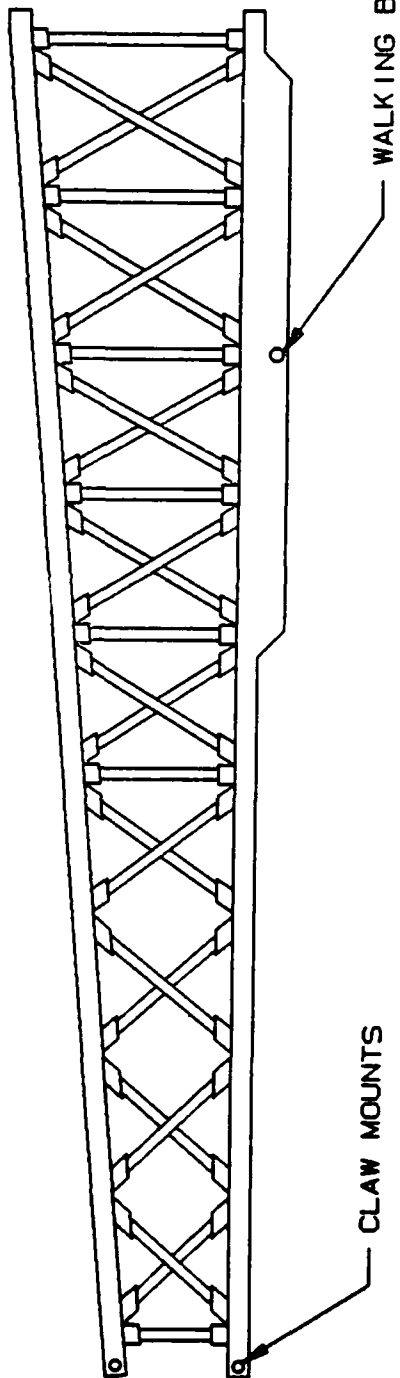
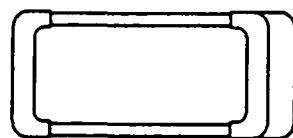
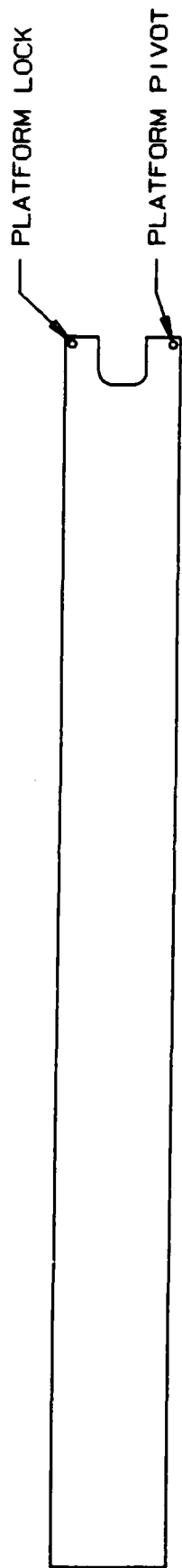
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TRAIL



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29 OCTOBER 1986
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96

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TRAIL

Item.....
Weight (lbm).....

302 EACH

Configuration Considerations..

WEIGHT
COST

BLAST OVERPRESSURE REFLECTION TO CANNONEER 1.
CLAW INDUCED LOAD DURING SKID.
CORNERING LOADS AND DEFLECTIONS DURING TOWING.
CARBON FIBER EPOXY
A1/SIC (6061-T6-25%)
5000 SERIES JOINTS
INSULATED STEEL BUSHINGS

Primary Material(s).....

Long Lead Items.....

EXTRUSION DIES, EXTRUSIONS, MANDREL

Primary Vendor(s).....

DWA ... NOD

Calendar Month.....	1986	1987	1988
	Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug..Sep..Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Au		
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Design/Layout/Matls. A			
Producibility.....			
Inspectability.....			
Structural Analysis.....			
Property/process tstg.....			
Detailing			
Long Lead Procurement.....			
Component Procurement.....			
Receive and Inspect.....			
Struct/funct testing.....			
Subassembly.....			
Final Assembly.....			
NOD Checkout/testing.....			
Array Testing.....			

☒ ..Funded under Contract

☐ ..Generic Data Acquisition not funded under Contract

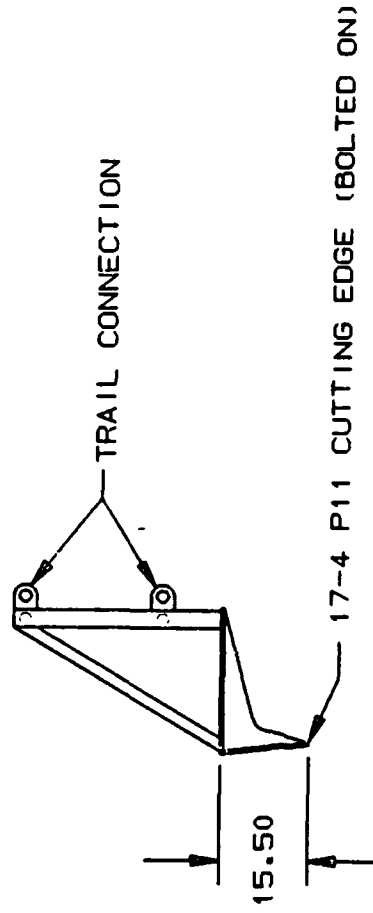
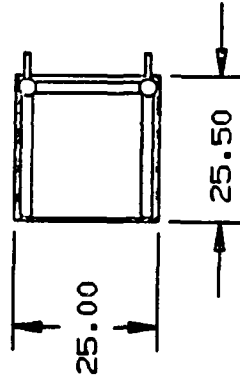
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BA

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CLAW



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29 OCTOBER 1986
BA

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CLAW

Item.....
Weight (lbm).....

55 EACH

Configuration Considerations..

MAINTENANCE OF LAY DURING "SPRING-BACK"
DURABILITY
WEIGHT
SIMPLICITY
TRAIL LOADING DURING SKID

Primary Material(s).....

A1/SIC (6061-T6-25%)
5000 SERIES JOINTS
INSULATION PASTE
17-4 PH EDGE

Long Lead Items.....

FROM TRAIL

Primary Vendor(s).....

DWA ... NOD

Calendar Month.....	1986												1987												1988																
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.		
MAC.....	B05..	B06..	B07..	B08..	B09..	B10..	C01..	C02..	C03..	C04..	C05..	C06..	C07..	C08..	C09..	C10..	C11..	C12..	C13..	C14..	C15..																				
Design/Layout/Matls.																																									
Productibility																																									
Inspectability																																									
Structural Analysis																																									
Property/process tstg.																																									
Detailing																																									
Long Lead Procurement																																									
Component Procurement																																									
Receive and Inspect																																									
Struct/funct Testing																																									
Subassembly																																									
Final Assembly																																									
MOO Checkout/testing																																									
Aray Testing																																									

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LOADING SYSTEM

Item.....
Weight (lbm).....

94

Configuration Considerations..

WEIGHT
RAM-D

ACHIEVING 4 ROUNDS PER MINUTE
MINIMUM VARIATION IN VELOCITY INTO FORCING CONE

Primary Material(s).....

KEVLAR-WRAPPED STEEL-LINED ACTUATOR
HYDRAULIC CONTROL VALVES
TITANIUM LOAD TRAY

Long Lead Items.....

NOD ... MAROTTA ... YORK

Primary Vendor(s).....

Calendar Month.....	1986												1987												1988															
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
MAC.....																																								
Design/Layout/Matrix.....																																								
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Subassembly.....																																								
Final Assembly.....																																								
MOD Checkout/Testing.....																																								
Army Testing.....																																								

Generic Data Acquisition not funded under Contract

LTHD

29 OCTOBER 1986

BA

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EMPLACEMENT CONTROLS

Item.....
Weight (lbm)..... 22

Configuration Considerations...
EMPLACEMENT/DISPLACEMENT TIMES
RAM-D
WEIGHT
COST

Primary Material(s)..... HYDRAULIC CONTROL VALVES

Long Lead Items.....

Primary Vendor(s)..... MAROTTA

Calendar Month.....	1986												1987												1988															
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
MAC.....																																								
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Productability.....																																								
Inspectability.....																																								
Structural Analysis.....																																								
Property/process tstg.....																																								
Detailing.....																																								
Long Lead Procurement.....																																								
Component Procurement.....																																								
Receive and Inspect.....																																								
Struct/Funct Testing.....																																								
Subassembly.....																																								
Final Assembly.....																																								
MOB Checkout/Testing.....																																								
Key Testing.....																																								

.....Funded under Contract ☐ ..Generic Data Acquisition not funded under Contract

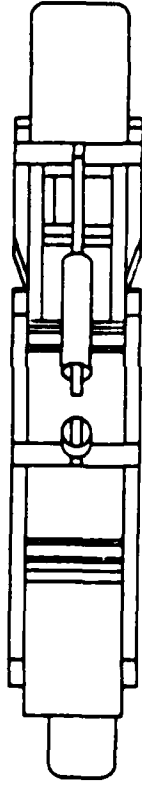
LTMD

29 OCTOBER 1986

BA

FMC

WHEEL AND BRAKE SYSTEM



— TRAIL MOUNTS

— WALKING BEAM PIVOT

LEAD WHEEL

— PULL PIN TO SEPARATE
A FRAMES FOR RETRACTION
INTO TRAILS

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29 OCTOBER 1986
BA



WHEEL AND BRAKE SYSTEM

652 TOTAL

OPERABILITY
WEIGHT
TOWING STABILITY

Configuration Considerations..

Primary Material(s)..... A1/SIC (6061-T6-25%) WALKING BEAMS | THERMOPLASTIC FENDERS
5000 SERIES JOINTS
INSULATED STEEL BUSHINGS
A1/SIC (2219-T7-30%) BRAKE ROTORS

Long Lead Items..... EXTRUSION DIES, EXTRUSIONS, WELD FIXTURES

Primary Vendor(s)..... DWA ... NOD ... KELSEY ... GOODYEAR

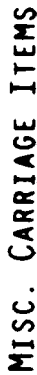
Calendar Month.....	1986												1987												1988															
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
MAC.....																																								
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Inspectability.....																																								
Structural Analysis.....																																								
Property/process tstg.....																																								
Detailing.....																																								
Long Lead Procurement.....																																								
Component Procurement.....																																								
Receive and Inspect.....																																								
Struct/Funct Testing.....																																								
Subassembly.....																																								
Final Assembly.....																																								
MOB Checkout/Testing.....																																								
Any Testing.....																																								

.....Funded under Contract ☐.....Generic Data Acquisition not funded under Contract

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29 OCTOBER 1986

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Item.....

Weight (lbm).....

Configuration Considerations...

WEIGHT
MINIMUM MAINTENANCE (NO GREASE ZERKS)
MINIMUM LOOSE PARTS

Primary Material(s).....

STEEL HARDLINE
TITANIUM FITTINGS
TITANIUM BOLTS
KEVLAR-WRAPPED STFL LIFT RINGS

Long Lead Items.....

MOD

Primary Vendor(s).....

[illegible]

.....Funded under Contract

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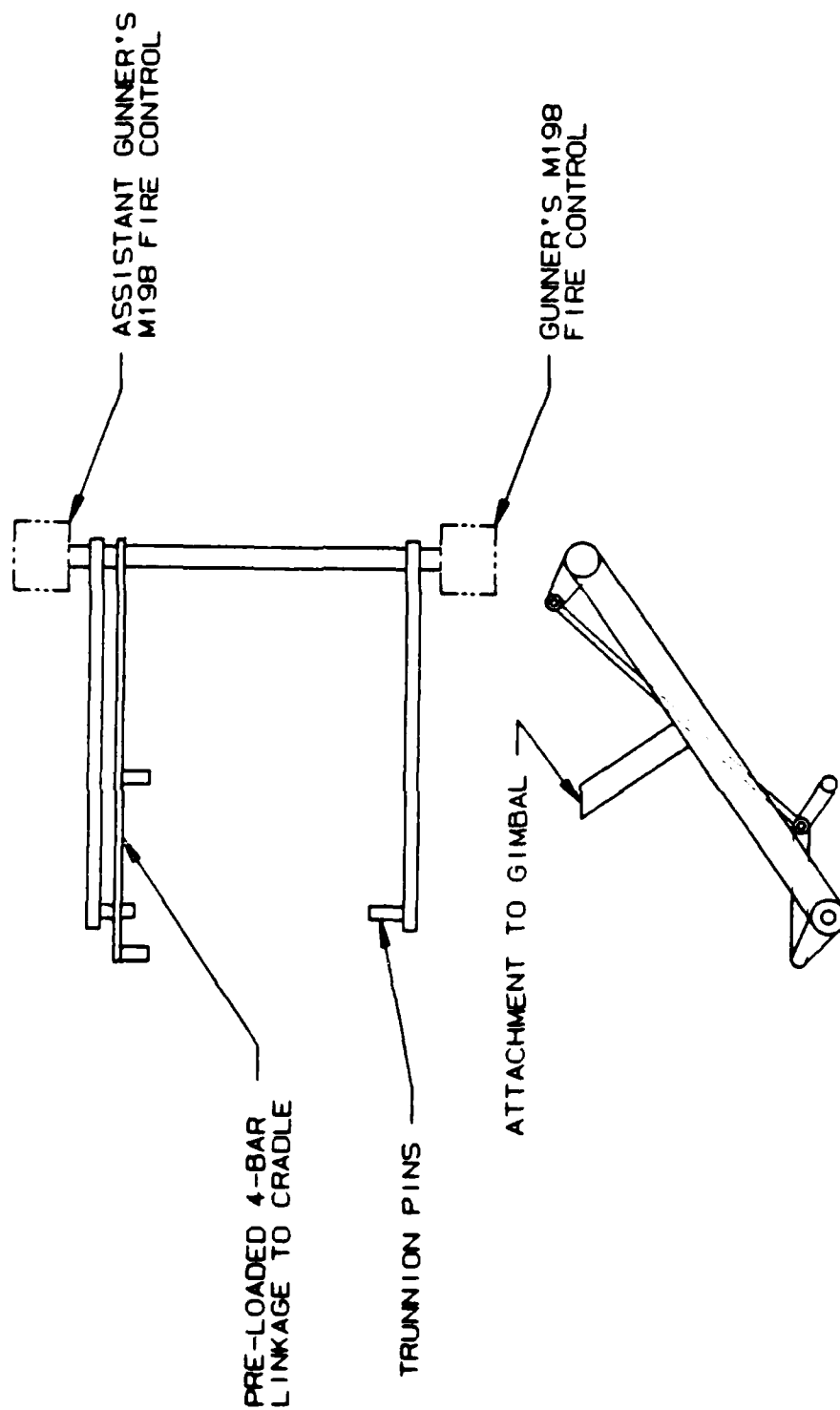
LTHD

29 OCTOBER 1986

BA

FMC

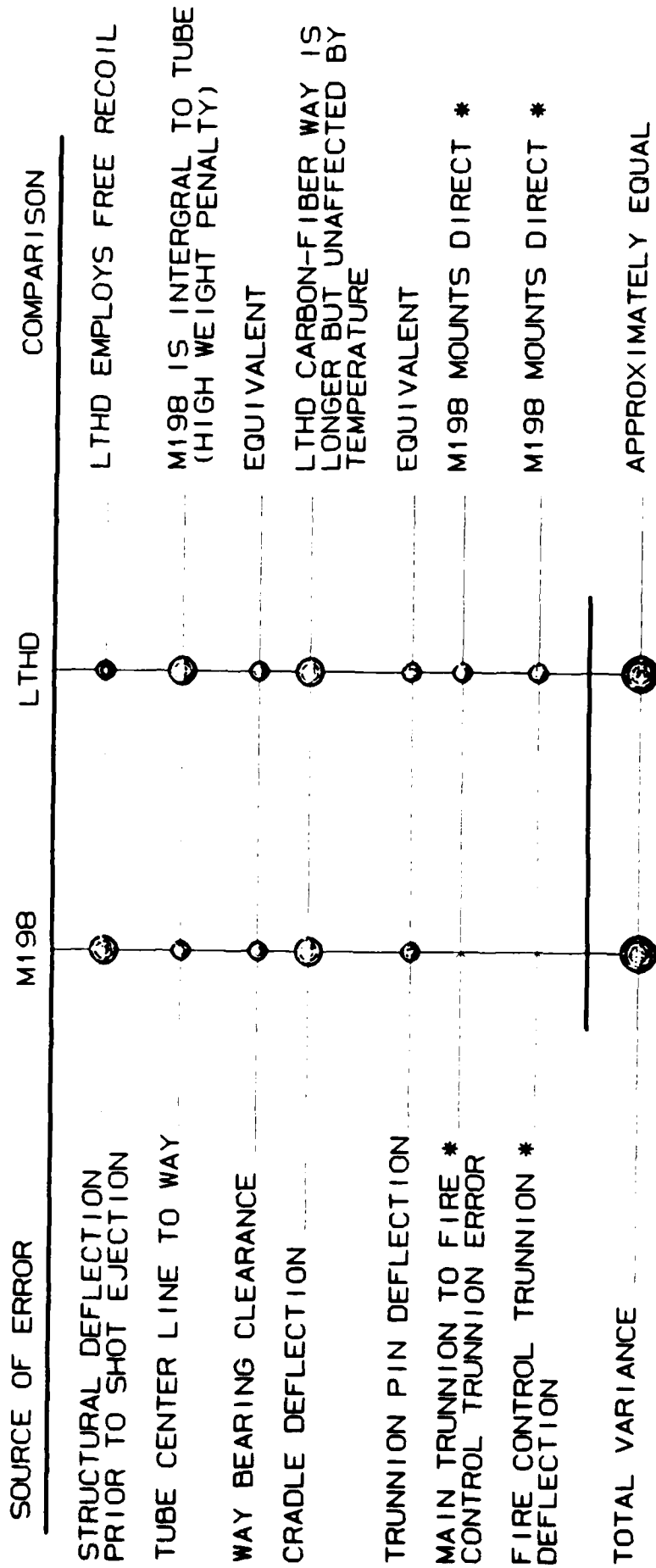
FIRE CONTROL-MEASUREMENT-METHOD



LTHD
29 OCTOBER 1986
BA



FIRE CONTROL-MEASUREMENT-ERROR



* SEPARATE FIRE CONTROL TRUNNION REQUIRED BECAUSE LTHD TRUNNION IS TOO LOW AND SHOCK LOADS MAY BE TOO HIGH TO MOUNT FIRE CONTROL DIRECTLY TO MAIN TRUNNION.

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29 OCTOBER 1986
BA

FMC

FIRE CONTROL - MEASUREMENT

Item.....
 Weight (lbm).....

144 + 38 = 182

Configuration Considerations..
 DIMENSIONAL STABILITY
 SHOCK ABSORPTION CAPABILITY
 WEIGHT
 COST

Primary Material(s).....
 CARBON FIBER EPOXY
 GFE

Long Lead Items.....
 Primary Vendor(s).....

NOD ... ARDEC

Calendar Month.....	1986												1987												1988																	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
MAC.....	B05..	B06..	B07..	B08..	B09..	B10..	C01..	C02..	C03..	C04..	C05..	C06..	C07..	C08..	C09..	C10..	C11..	C12..	C13..	C14..	C15..																					
Design/Layout/Matls.....																																										
Productibility.....																																										
Inspectability.....																																										
Structural Analysis.....																																										
Property/process tstng.....																																										
Detailing.....																																										
Long Lead Procurement.....																																										
Component Procurement.....																																										
Receive and Inspect.....																																										
Struct/Funct Testing.....																																										
Subassembly.....																																										
Final Assembly.....																																										
WOP Checkout/Testing.....																																										
Army Testing.....																																										

.....Funded under Contract

☐...Generic Data Acquisition not funded under Contract

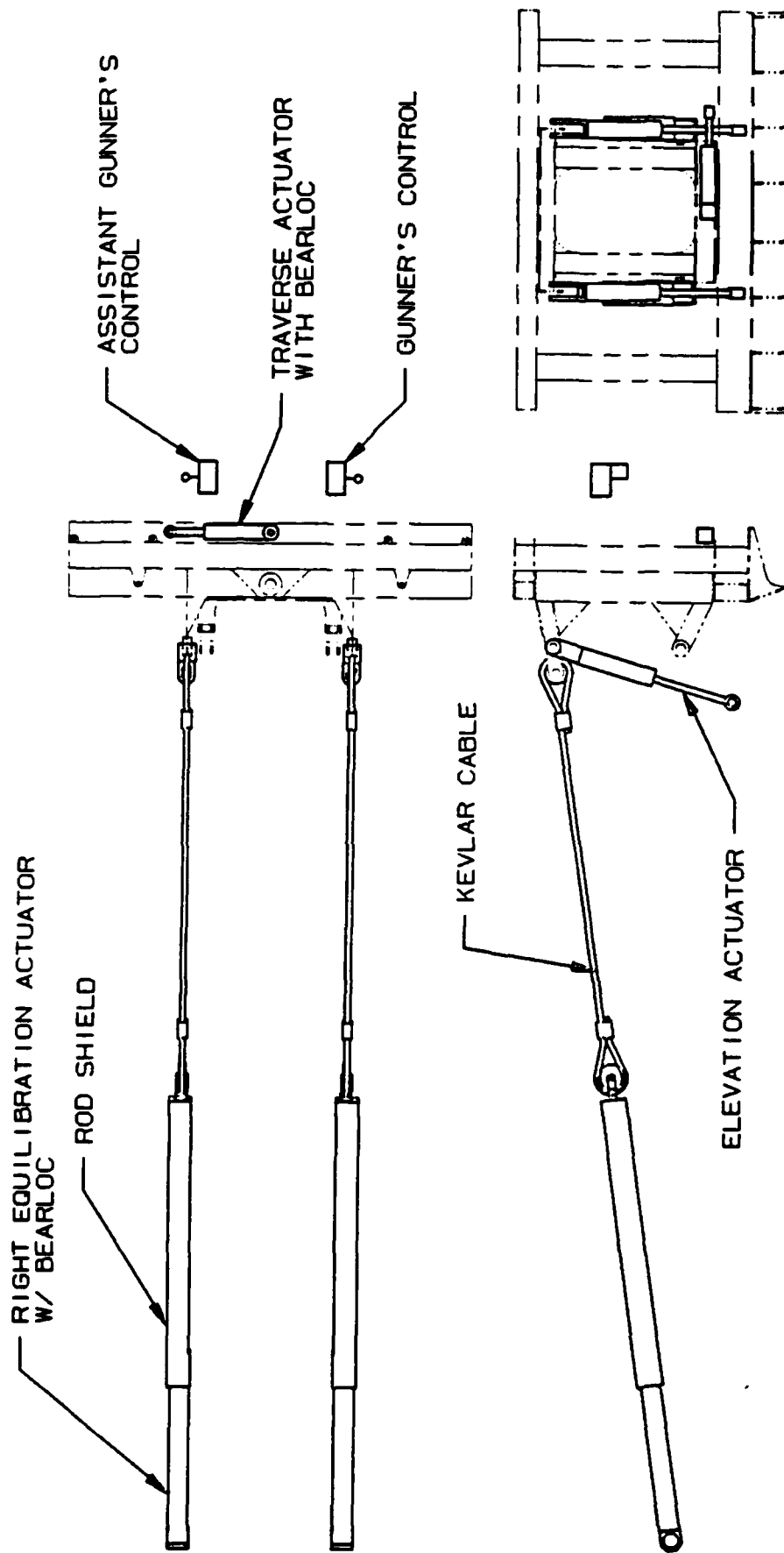
LTHD

29 OCTOBER 1986

BA

FMC

FIRE CONTROL-TUBE LAY



LTHD
29 OCTOBER 1986
BA



Weight (lbm)..... 673

Configuration Considerations..

Primary Material(s).....	
	KEVLAR WRAPPED STEEL LINED ACTUATORS AND ACCUMULATORS
	KEVLAR CABLE
	JOYSTICK CONTROLS

Long Lead Items.....	YORK ... MAROTTA ... CORTLAND
Primary Vendor(s).....	

Calendar Month.....	1986.....	1987.....	1988.....
Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug..Sep..Oct..Nov..Dec..Jan..Feb..Mar..Apr..May..Jun..Jul..Aug			
MAR.....	B05..B06..B07..B08..B09..B10..C01..C02..C03..C04..C05..C06..C07..C08..C09..C10..C11..C12..C13..C14..C15..		
Design/Layout/Matls Assn.....			
Productibility.....			
Inspectability.....			
Structural Analysis.....			
Property/process tstng.....			
Detailling			
Long Lead Procurement.....			
Component Procurement.....			
Receive and Inspect.....			
Construct/Funct Testing.....			
Subassembly.....			
Final Assembly.....			
100% Checkout/Testing.....			
Ray Testing.....			

Funded under Contract	Generic Data Acquisition not funded under Contract
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CHIT

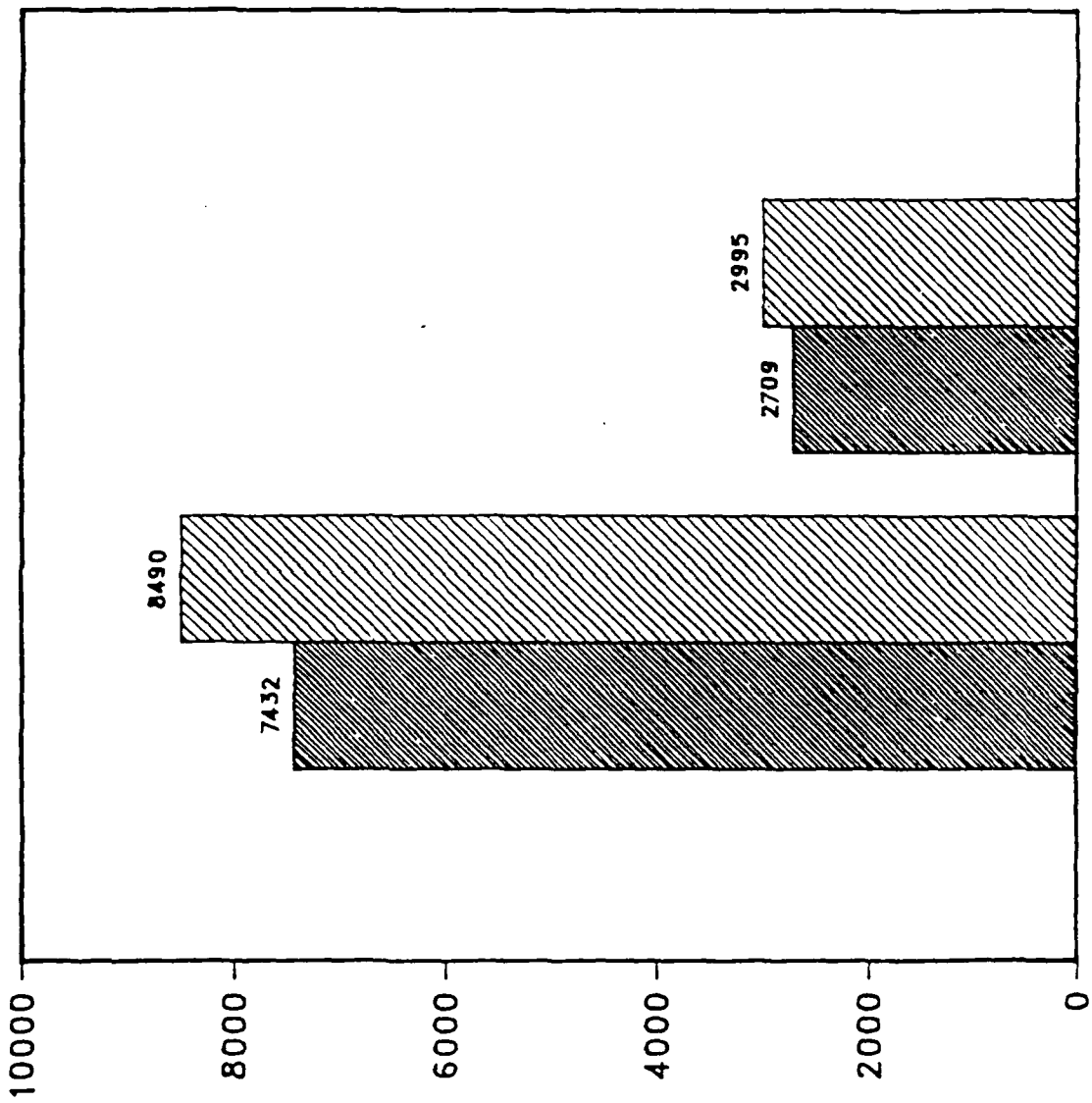
29 OCTOBER 1986

BA

LTHD Hydraulic System Reliability Comparison Study



MRBF (Rounds) ▨ Baseline ▩ Current



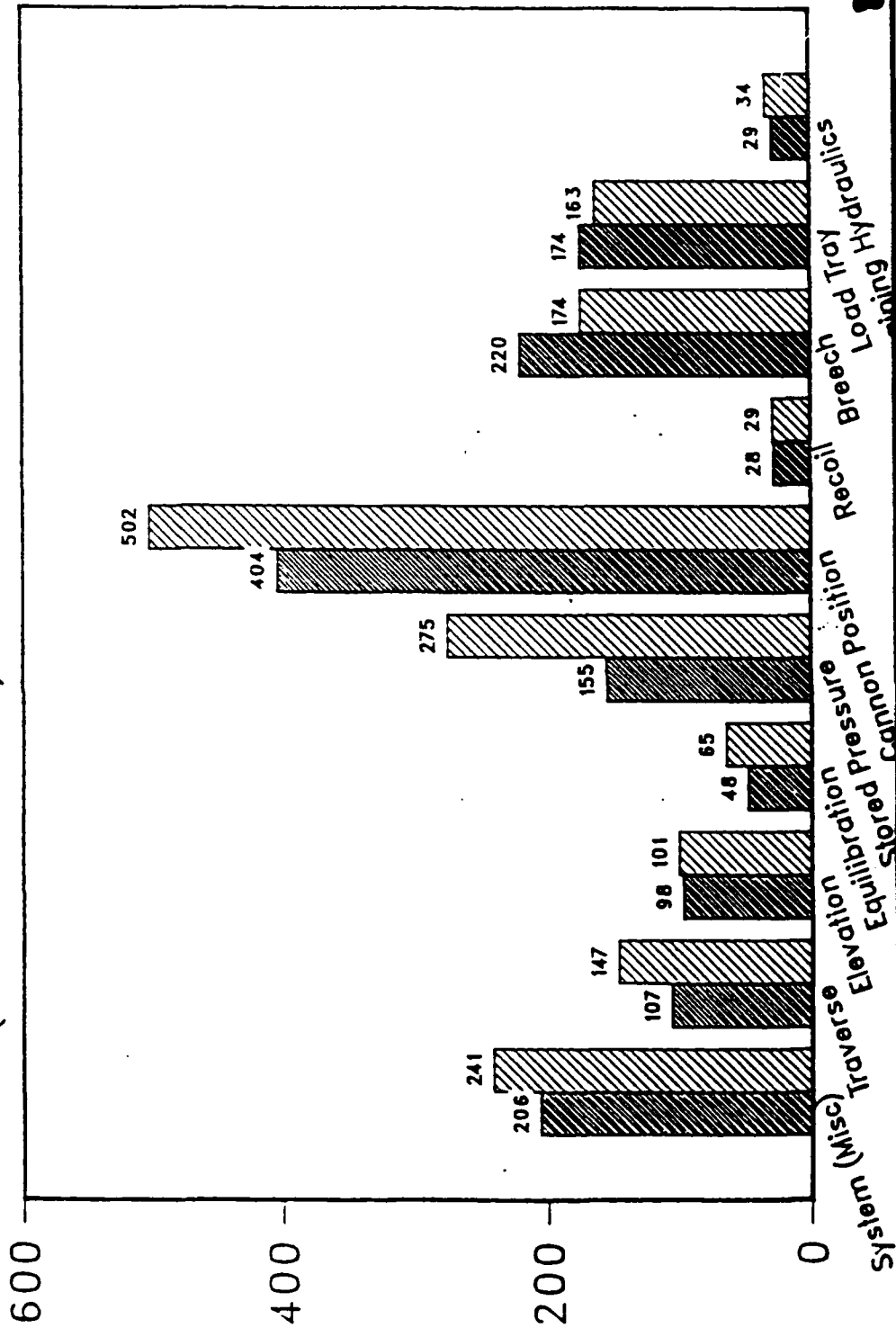
Mission Critical

Basic



LTHD Hydraulic Subsystem Mission Critical Reliability Comparison Study

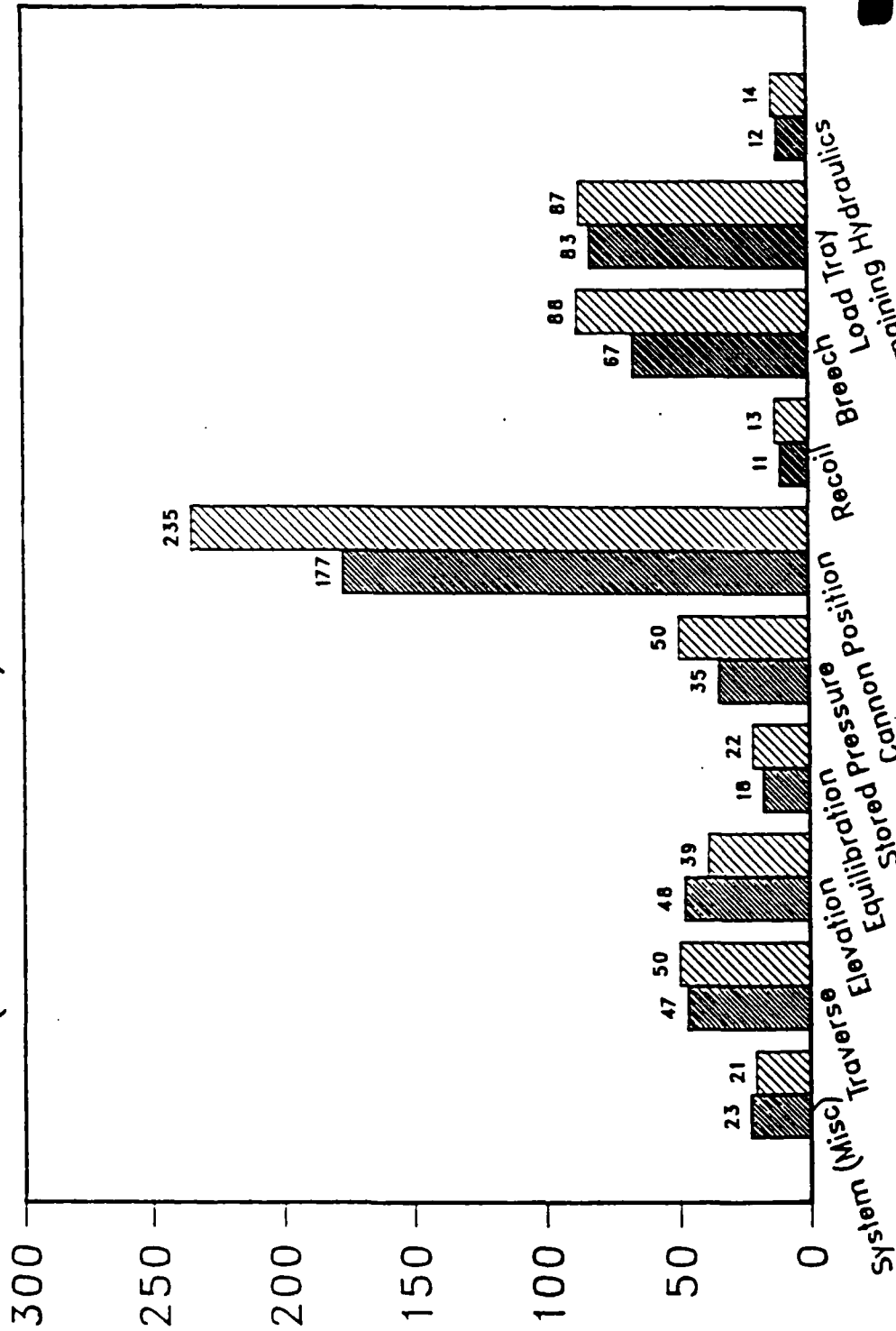
F1 MRBF (Thousand Rounds) BASELINE Current





LTHD Hydraulic Subsystem Basic Reliability Comparison Study

F3 MRBF (Thousand Rounds) BASELINE Current





LTHD HYDRAULIC SYSTEM DESIGN CHANGES EFFECT ON RELIABILITY (1 OF 2 TABLES)

CHANGES	MISSION CRITICAL RELIABILITY (FAILURE RATE CHANGE) (fpmr) *	BASIC RELIABILITY (FAILURE RATE CHANGE) (fpmr) *
BASELINE HYDRAULIC CONFIGURATION o REDUNDANT HAND PUMPS AND BREECH VALVES o HIGH QUANTITY OF PIPES AND HOSES	SYSTEM = 134.6 fpmr (MRBF = 7,432)	SYSTEM = 369.1 fpmr (MRBF = 2,709)
ELIMINATED PLATFORM (OUTRIGGERS) AND RAMMER HYDRAULICS	BETTER (-34.3 fpmr)	BETTER (-80.4 fpmr)
ADDED WHEEL AND LOAD POSITION HYDRAULICS	WORSE (+29.7 fpmr)	WORSE (+72.0 fpmr)
DECREASED QUANTITY OF HOSES, PIPES, AND FITTINGS; ADDED SLIP RINGS	BETTER (-3.8 fpmr)	BETTER (-13.7 fpmr)
ADDED REDUNDANT CONTROL FUNCTIONS FOR GUNNER AND ASSISTANT GUNNER	BETTER (-5.4 fpmr)	WORSE (+13.7 fpmr)
ELIMINATED REDUNDANT BREECH VALVES	WORSE (+0.9 fpmr)	BETTER (-1.5 fpmr)
SIMPLIFIED RECOIL HYDRAULICS (ELIMINATED ACCUMULATOR, VALVE, CIRCUIT BREAKER)	BETTER (-1.6 fpmr)	BETTER (-10.7 fpmr)

(*) - FAILURES PER MILLION ROUNDS

LTHD
29 OCT 1986
115



LTHD HYDRAULIC SYSTEM DESIGN CHANGES EFFECT ON RELIABILITY (2 OF 2 TABLES)

CHANGES	MISSION CRITICAL RELIABILITY (FAILURE RATE CHANGE) (fpmr)*	BASIC RELIABILITY (FAILURE RATE CHANGE) (fpmr)*
SIMPLIFIED EQUILIBRATION HYDRAULICS (ELIMINATED VALVES, GAGES, CIRCUIT BREAKER)	BETTER (-1.7 fpmr)	BETTER (-6.7 fpmr)
SIMPLIFIED STORED PRESSURE HYDRAULICS (ELIMINATED CHECK VALVES, CIRCUIT BREAKER)	BETTER (-1.3 fpmr)	BETTER (-4.2 fpmr)
SIMPLIFIED TRAVERSE HYDRAULICS (ELIMINATED LOCK VALVE, PRESS GAGE)	BETTER (-1.3 fpmr)	BETTER (-3.4 fpmr)
INCREASED LOAD TRAY HYDRAULICS (ADDED FLOW CONTROL VALVE)	WORSE (+1.4 fpmr)	WORSE (+2.3 fpmr)
MISCELLANEOUS CHANGES	WORSE (+0.6 fpmr)	BETTER (-2.6 fpmr)
CURRENT HYDRAULIC CONFIGURATION o REDUNDANT GUNNER AND ASSIST GUNNER FUNCTIONS o LESS PIPING, HOSES, AND FITTINGS o LESS COMPLEX SYSTEM	SYSTEM = 117.8 fpmr (MRBF = 8,490)	SYSTEM = 333.9 fpmr (MRBF = 2,995)

(*) - FAILURES PER MILLION ROUNDS

LTHD

29 Oct 1986

EQ

114

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

QUALITY ASSURANCE PROGRAM PLAN

- 0 AN UPDATED PRELIMINARY DRAFT WAS SUBMITTED FOR REVIEW ON 1 OCTOBER 1986
- 0 QA/QC PERSONNEL MET WITH ARDEC PERSONNEL ON 7 OCTOBER 1986 AT FMC (NOD)
- 0 AFTER REVIEW AND INCORPORATION OF COMMENTS RECEIVED, AN UPDATED PLAN WAS DELIVERED ON 27 OCTOBER 1986
- 0 A FINAL PLAN WILL BE SUBMITTED WITH OTHER DOCUMENTS PRIOR TO THE END OF PHASE II

15
LTHD
29 OCTOBER 1986
EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

QUALITY ASSURANCE PROGRAM PLAN

ACTION ITEMS FROM MEETING

0 ACTION ITEM: ADD A SECTION ON LABORATORY TESTING TO THE QA PROGRAM PLAN

STATUS: THE LABORATORY TESTING HAS BEEN ADDED (PARAGRAPH 4.2.5.E)

0 QUESTIONS: Q - WHAT HAPPENS WHEN TESTING IS REQUIRED BY A VENDOR AND
AND THE VENDOR IS UNABLE TO DO THE TESTING?

ANSWERS: A - THAT FMC (NOD) WOULD ASSUME RESPONSIBILITY FOR TESTS
VENDORS ARE UNABLE TO DO.

Q - HOW DOES THE QA DEPARTMENT HANDLE IMPOSING ON VENDORS
SPECIFICATIONS AND QA REQUIREMENTS?

A - THE FMC (NOD) QA PROCUREMENT SECTION WILL IMPOSE ON OUR
SUPPLIERS THROUGH THE PURCHASE ORDER, SPECIFICATION AND
QA REQUIREMENTS OF THE CONTRACT.

116
LTMD
29 OCTOBER 1986
EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

PRODUCT ASSURANCE TEST PLAN

- 0 AN INITIAL PRELIMINARY DRAFT WAS SUBMITTED FOR REVIEW ON
1 OCTOBER 1986
- 0 PA TEST PERSONNEL MET WITH ARDEC PERSONNEL ON 7 OCTOBER 1986
AT FMC NORTHERN ORDNANCE DIVISION
- 0 AFTER REVIEW AND INCORPORATION OF COMMENTS RECEIVED, AN UPDATED
PLAN WAS DELIVERED ON 27 OCTOBER 1986
- 0 IT IS EXPECTED THAT THE PA PROGRAM PLAN WILL BE A "LIVING DOCUMENT"
THROUGHOUT PHASE II
- 0 THE FINAL PLAN WILL BE SUBMITTED WITH OTHER DOCUMENTS AT THE END
OF PHASE II

117

LTHD
29 OCTOBER 1986
EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

TEST PLAN

ACTION ITEMS FROM 7 OCTOBER MEETING

- 0 ACTION ITEM: SYSTEM REQUIREMENTS SHOULD BE INCLUDED IN THE PA PROGRAM PLAN AND TEST PROCEDURES SHOULD ALSO BE FORMED TO THE OPERATIONAL REQUIREMENTS
- STATUS: SYSTEM REQUIREMENTS WERE IN THE SCOPE OF THE PLAN, BUT NOT SPECIFICALLY IDENTIFIED. THE UPDATED DRAFT HAS CLARIFIED AND EXPANDED THE SYSTEM REQUIREMENTS SECTION. SEE PART 1, SECTION 1.0 OF PLAN
- 0 ACTION ITEM: DOCUMENT THAT LOW TEMPERATURE CONDITIONS ARE NOT A PROBLEM WITH COMPOSITES
- STATUS: LOW TEMPERATURE TESTS (-65°) OF THE COMPOSITE MATERIALS IN QUESTION WILL BE PERFORMED
- 0 ACTION ITEM: COMPATIBILITY BETWEEN SEALS AND COMPOSITE MATERIALS (CONCERNS HYDRAULICS) TO BE ADDRESSED
- STATUS: THE COMPOSITE MATERIAL IN QUESTION IS THE KEVLAR/EPOXY WRAPPING ON THE HYDRAULIC CYLINDERS AND ACCUMULATORS. RESEARCH INDICATED THAT HYDRAULIC OIL DOES NOT VISIBLY DAMAGE THE COMPOSITE (REF. OTR 28-60005, 5.2.5 IMMERSION, YORK IND, INC.) TESTS ALSO SHOW THAT HIGH HUMIDITY (90%) HAS NO DETRIMENTAL EFFECT ON THE COMPOSITE MATERIAL'S PERFORMANCE BETWEEN -65°F AND 160°F

118

LHD

29 OCTOBER 1986

EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

TEST PLAN

ACTION ITEMS FROM 7 OCTOBER MEETING

0 ACTION ITEM: DOCUMENT THAT ETHYLENE GLYCOL AND HYDRAULIC OIL ARE NOT A PROBLEM TO COMPOSITES.

STATUS: CHEMICAL RESISTANCE TESTS ON THE COMPOSITE MATERIALS WILL BE PERFORMED USING HYDRAULIC OIL AND ETHYLENE GLYCOL. INFORMATION ON ANY PREVIOUS TESTS ON THE EFFECT OF ETHYLENE GLYCOL HAS BEEN REQUESTED FROM YORK INDUSTRIES, INC.

0 QUESTION: WHAT TYPE OF ENVIRONMENT TESTING WILL BE CONDUCTED ON HYDRAULIC COMPONENTS?

ANSWER: ENVIRONMENTAL TESTING OF HYDRAULICS IS PRESENTLY NOT FUNDED BY CONTRACT.

119

LTHD
29 OCTOBER 1986
EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

PRODUCT ASSURANCE TEST PLAN

TEST BREAKDOWN STRUCTURE

0 COMPOSITE MATERIAL TESTING

0 INTEGRATED SYSTEM TESTING

0 STRUCTURAL TESTING

0 SYSTEM LEVEL TESTING

LTHD
29 OCTOBER 1986
EQ

120

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR



COMPOSITE MATERIAL TESTING

- 0 LOW TEMPERATURE/HIGH TEMPERATURE/HIGH HUMIDITY TENSILE,
COMPRESSIVE AND SHEAR STRENGTH TESTING
- 0 PIN HOLE JOINT TEST
- 0 HIGH TEMPERATURE/HIGH HUMIDITY DOUBLE LAP SHEAR STRENGTH
TEST
- 0 HIGH TEMPERATURE/HIGH HUMIDITY PEEL STRENGTH
- 0 CHEMICAL RESISTANCE OF MATERIAL TESTING

12-1
LTMD
29 OCTOBER 1986
EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

INTEGRATED SYSTEM TESTING

0 SUBUNIT HYDROSTATIC TESTING

0 SUBUNIT HYDRAULIC TESTING

122-
LTHD
29 OCTOBER 1986
EQ



LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

STRUCTURAL TESTING

- 0 SLIDE TRUNNION JOINT STRENGTH TEST
- 0 TRAILS STRUCTURAL TEST
- 0 CRADLE STRUCTURAL TEST
- 0 GIMBAL STRUCTURAL TEST
- 0 PLATFORM ASSEMBLY STRUCTURAL TEST

123

LTHD
29 OCTOBER 1986
EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

SYSTEM LEVEL TESTING

SYSTEM ALIGNMENT:

0 TRAVERSE LIMITS

0 ELEVATION LIMITS

0 TRAVERSE SYSTEM PLANE

0 ELEVATION SYSTEM SLEW

0 FIRE CONTROL ALIGNMENT

LTJHD 124-
29 OCTOBER 1986
EQ

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

SYSTEM LEVEL TESTING

FUNCTIONAL:

- 0 LOAD TRAY TESTS
- 0 TRAIL WHEELS OPERATION
- 0 HYDRAULIC INTERLOCK

LTHD
29 OCTOBER 1986
EQ

125



LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

FMC

SYSTEM LEVEL TESTING

0 LOAD DISPLACEMENT

0 EMPLACEMENT

0 SPEED SHIFTING

0 DISPLACEMENT

0 TOWING STABILITY

0 SYSTEM PROOF FIRING

LTHD
29 OCTOBER 1986
EQ

126

B/700

15 JAN 87
TECHNICAL PRESENTATION
PHASE II

FMC

155MM LIGHTWEIGHT TOWED HOWITZER DEMONSTRATION PROGRAM

CONTRACT DAAA21-86-C-0047

QUARTERLY PROGRAM REVIEW

15 JANUARY 1987

AT ARDEC

PRESENTED BY:

ROBERT RATHE, PROGRAM MANAGER

BART ANDERSON, PROJECT ENGINEER

JEFF IRELAND, MECHANICAL ENGINEER

SCOTT DACKO, MECHANICAL ENGINEER

TOM RUDOLF, COMPOSITES ENGINEER

FRED APPLETON, MANUFACTURING PLANNING

LTHD I

15 JANUARY 1987

RR

SCOPE AND PURPOSE

Quarterly Program Review and Design Review

DATE: Thursday, January 15, 1987, at ARDEC - 8:30 am - 4:00 pm

REFERENCE: Analysis summary and information which will be provided by January 13, 1987. Detailed drawings and layouts - 2 copies to be provided by January 13, 1987

Objectives:

- o Review design details and critique design and analysis
- o Review program schedule and status and identify areas of concern

List of documents for review:

- o Program plan - provided update October 1, 1986
- o Test plans - provided 8 December 1986
- o Detailed drawings and layouts of components - provide by January 13, 1987
- o Hydraulic functional diagram - provide by January 13, 1987
- o FEM analysis results with supporting information - provide by January 13, 1987

Action items will be discussed at the end of each session.

4956F

AGENDA FOR MEETING ON THURSDAY, JANUARY 15, 1987

8:30 am	Introductions	Robert Rathe
8:35 am	Program Status Schedule Review/Long Lead Item List Financial Status Problems Requiring Resolution Future planned effort Risk Assessment/Procurement Plans	Robert Rathe
9:00 am	System Overview and Assembly Procedures	Bart Anderson
10:00 am	Systems Structural Analysis	Larry Libhardt
10:45 am	Operational Review	Scott Dacko
11:15 am	Cannon Assembly and Interface Drawings Auto Primer/Muzzle Brake	Bart Anderson
11:30 am	Recoil System Assembly and Analysis	Jeff Ireland
12:00 noon	Lunch	
1:00 am	Cradle Assembly	Tom Rudolf
1:30 pm	Gimbal, Platform and Trails	Bart Anderson
2:00 pm	Fire Control Assembly	Scott Dacko
2:30 pm	Hydraulic System Review	Jeff Ireland
3:00 pm	Manufacturing Plans	Fred Appleton
3:30 pm	Test Plans - Composites	Tom Rudolf
3:45 pm	Action Items and Wrap-Up	Robert Rathe
4:00 pm	Adjourn	

4996F

W

FMC

DESCRIPTION	1986						1987			
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
PHASE II TASKS:										
DEVELOP DETAILED DESIGN	X									
CONDUCT ANALYSES	X									
CONDUCT OPTIMIZATION			X							
PREPARE SCHEMATICS										
UPDATE SYSTEM SPECS										
PREPARE DRAWINGS										
DEVELOP CONTROL LOGIC										
SPECIFY MATERIALS										
SELECT FABRICATORS										
WRITE FAB/QA PROCEDURES										
DEVELOP PURCH. DESCRIPTION										
ORDER LONG LEAD ITEMS										
CONDUCT TRADE STUDIES										
DEVELOP MAT. TEST PLANS										
PREPARE TEST SAMPLES										
DEVELOP ACCEPTABLE PLAN										
DEVELOP R&M REQUIREMENTS										
DEVELOP QUAL. PROGRAM PLAN										
UPDATE DYN. ANALYSIS REPORT										
UPDATE FHA										
INTERNAL REVIEWS										
CUSTOMER REVIEWS										

--- Denotes schedule slippage of tasks.

LTHD ↑
15 JANUARY 1987
RR

4996F

4



PROGRESS AGAINST PLANS FOR DECEMBER

PLANS

1. COMPLETE VALIDATION OF FINITE ELEMENT MODELS FOR MAJOR STRUCTURAL COMPONENTS AND CONDUCT DESIGN ITERATIONS.
2. COMPLETE VALIDATION OF SYSTEM DYNAMIC MODEL.
3. COMPLETE DETAILED BILL OF MATERIALS ALONG WITH WEIGHT ANALYSIS.
4. INITIALIZE MANUFACTURING REVIEW AND VENDOR SELECTION FOR LONG LEAD ITEMS.
5. SUBMIT COST PROPOSAL WHICH REFLECTS INCREASED SPENDING LEVELS FOR TRAVEL TEST AND DESIGN.
6. COMPLETE PRELIMINARY DESIGN FOR REMAINING COMPONENTS.

PROGRESS

PRESENTED PRELIMINARY RESULTS OF ANALYSIS DEC. 17TH AND MORE DETAILED RESULTS IN REPORT FORMAT JANUARY 12TH.
MODEL HAS BEEN VALIDATED AND IS BEING USED FOR DYNAMIC ANALYSIS.
APPROXIMATELY 85% COMPLETE. WE HAVE IDENTIFIED AREAS TO REDUCE WEIGHT TO MEET 9,000 LB. TARGET.
ACTIVITY STARTED END OF DECEMBER WHEN ADEQUATE DETAIL WAS AVAILABLE
COST PROPOSAL SUBMITTED DECEMBER 17, 1986.

ACTIVITY ON GOING WITH DESIGN LAYOUT FOR MUZZLE BRAKES, FRONT MANIFOLD AND FIRE CONTROL LINKAGE 80% COMPLETE.

LTHD 5

15 JANUARY 1987

RR

FMC

PLANS FOR JANUARY

1. COMPLETE AUDITING OF ANALYSIS OF GUN LAYING SYSTEM.
COMPLETE AUDITING OF ANALYSIS OF RECOIL SYSTEM.
COMPLETE RELIABILITY ASSESSMENT AND PRELIMINARY HAZARD ANALYSIS.
INITIATE ANALYSIS OF LOAD TRAY MECHANISM.
2. COMPLETE DETAILING OF LONG LEAD ITEMS.
3. PROCEED WITH MATERIAL TESTING AND EVALUATION WHEN TEST PLANS ARE APPROVED.
4. SUBMIT TEST PLANS FOR HYDRAULIC CIRCUIT EVALUATION OF:
 - A. TRAVERSE AND ELEVATION CONTROL CIRCUIT
 - B. LONG STROKE INERTIAL RAMMER CONTROL CIRCUIT
5. COMPLETE SOURCE CONTROL DRAWINGS FOR MAJOR HYDRAULICS COMPONENTS.
6. DEVELOP TEST PLAN FOR STRUCTURES TESTING OF MAJOR STRUCTURAL COMPONENTS.
7. COMPLETE PRELIMINARY DESIGN FOR REMAINING COMPONENTS AND COMPLETE DETAILED BILL OF MATERIALS WITH ANALYSIS DRIVEN WEIGHTS.
8. MAKE-BUY DECISIONS AND INITIATE PROCUREMENT FOR THE LONG LEAD ITEMS.

LTHD 6
15 JANUARY 1987
RR

FMC

WBS Element Description	Probability Factors			Consequence Factors			Avg. Prob. Factor	Avg. Consequ. Factor	Risk Factor	Rating
	Pm	Pc	Pd	Ct	Cc	Cs				
11100 Int/assby	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557	L-M
11200 Cannon										
Tube	GFE									
Muzzel Brake	0.3	0.3	0.5	0.3	0.3	0.3	0.367	0.300	0.557	L-M
Breech	GFE									
Primer Autoloader	0.3	0.3	0.5	0.5	0.1	0.1	0.367	0.233	0.514	L-M
* Rail Assembly	0.3	0.1	0.3	0.3	0.1	0.3	0.233	0.233	0.412	
11300 Carriage										
Cradle	0.5	0.3	0.9	0.9	0.3	0.3	0.567	0.500	0.783	M-H
Tralls	0.5	0.3	0.3	0.5	0.3	0.3	0.367	0.367	0.599	M
Gimbal	0.5	0.3	0.3	0.5	0.3	0.3	0.367	0.367	0.599	M
Platform	0.3	0.1	0.3	0.3	0.3	0.3	0.233	0.300	0.463	
Wheel units	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
Recoil Mechanism	0.5	0.5	0.5	0.5	0.3	0.3	0.500	0.367	0.683	M
Equilibrators	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557	M
Hydraulics	0.5	0.5	0.5	0.7	0.5	0.5	0.500	0.567	0.783	M-H
Inertial Rammer	0.3	0.3	0.3	0.5	0.3	0.3	0.367	0.367	0.599	M
Load Tray	0.3	0.1	0.1	0.1	0.1	0.1	0.167	0.100	0.250	
Spade	0.3	0.1	0.1	0.3	0.1	0.1	0.167	0.167	0.306	
11400 Fire Control	GFE									
Elevation	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
Traverse	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
* Linkage	0.3	0.1	0.1	0.1	0.1	0.1	0.167	0.100	0.250	

Pm = probability of failure due to maturity
 Pc = probability of failure due to complexity
 Pd = probability of failure due to dependency on other items
 Ct = consequence of failure due to technical factors
 Cc = consequence of failure due to changes in cost
 Cs = consequence of failure due to changes in schedule
 * = Added to list

NOTE: Claws were deleted

LTD 7
 15 JANUARY 1967
 RR

FMC

ESTIMATE OF LTHD
WEIGHT AS OF 14 JAN 87

SOURCE

ANALYSIS

(ITEMS ANALYZED = 26% OF TOTAL WEIGHT)

9,149

ENGINEERING

(ITEMS CALCULATED FROM DESIGNS = 8,510 LBM OR 93% OF TOTAL WEIGHT)

9,123

LTHD 8
15 JANUARY 1987
BA -1

FMC

DESIGN UPDATE

SYSTEM OVERVIEW

MAJOR ITEMS

INTERFACE DETAILS

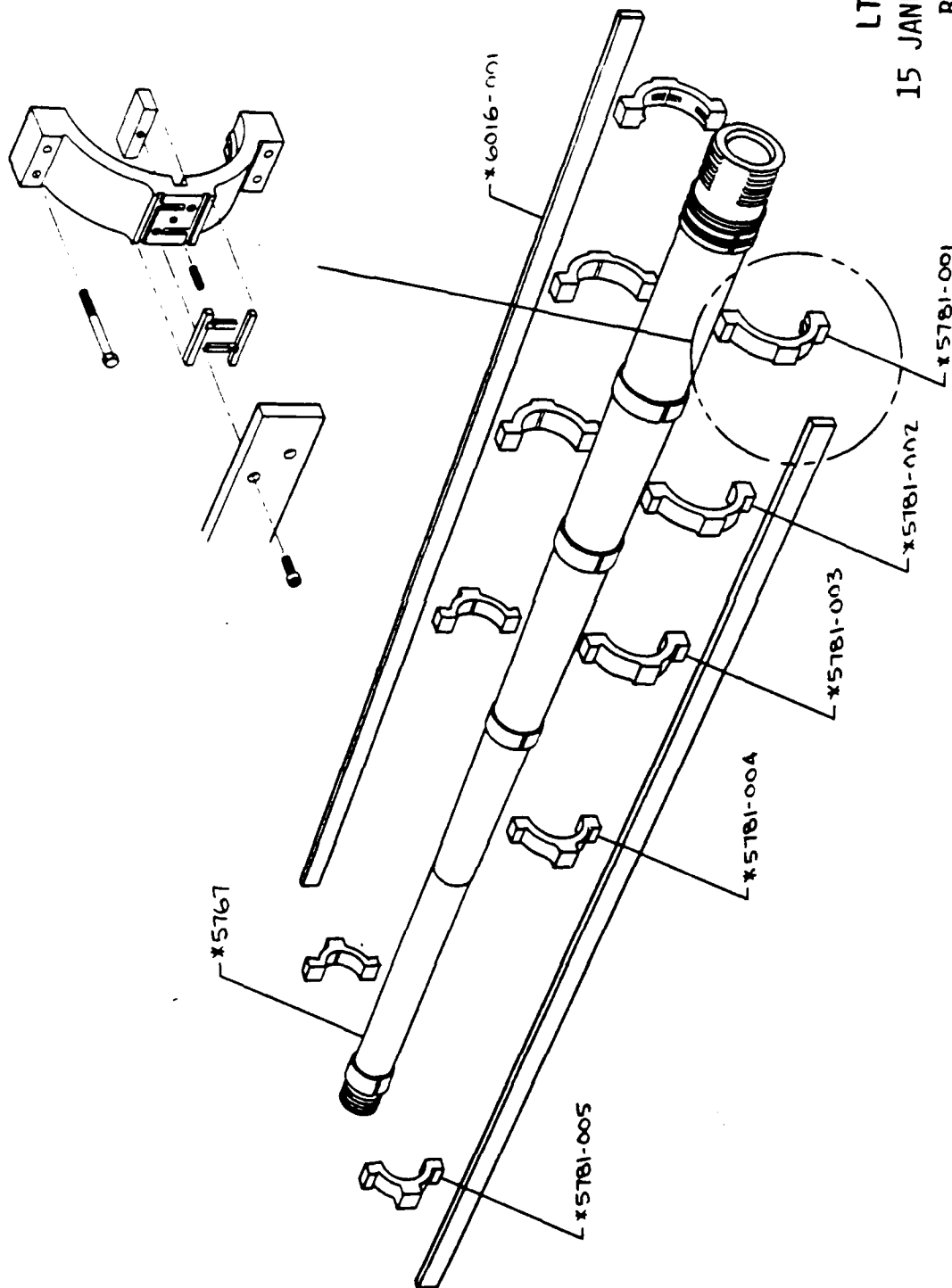
LTHD 9
15 JANUARY 1987
BA - 2

[REDACTED]

[illegible]

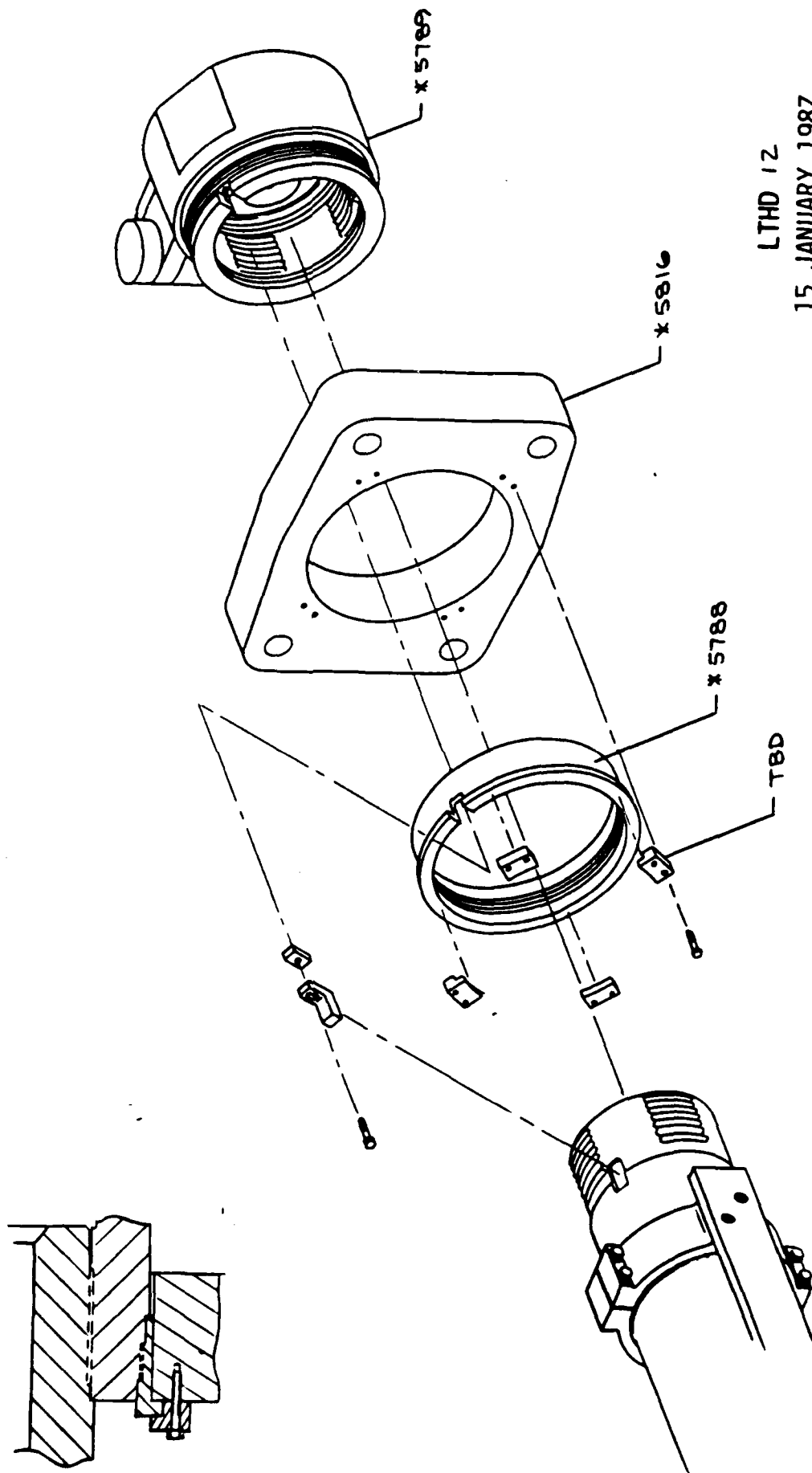
10

FMC



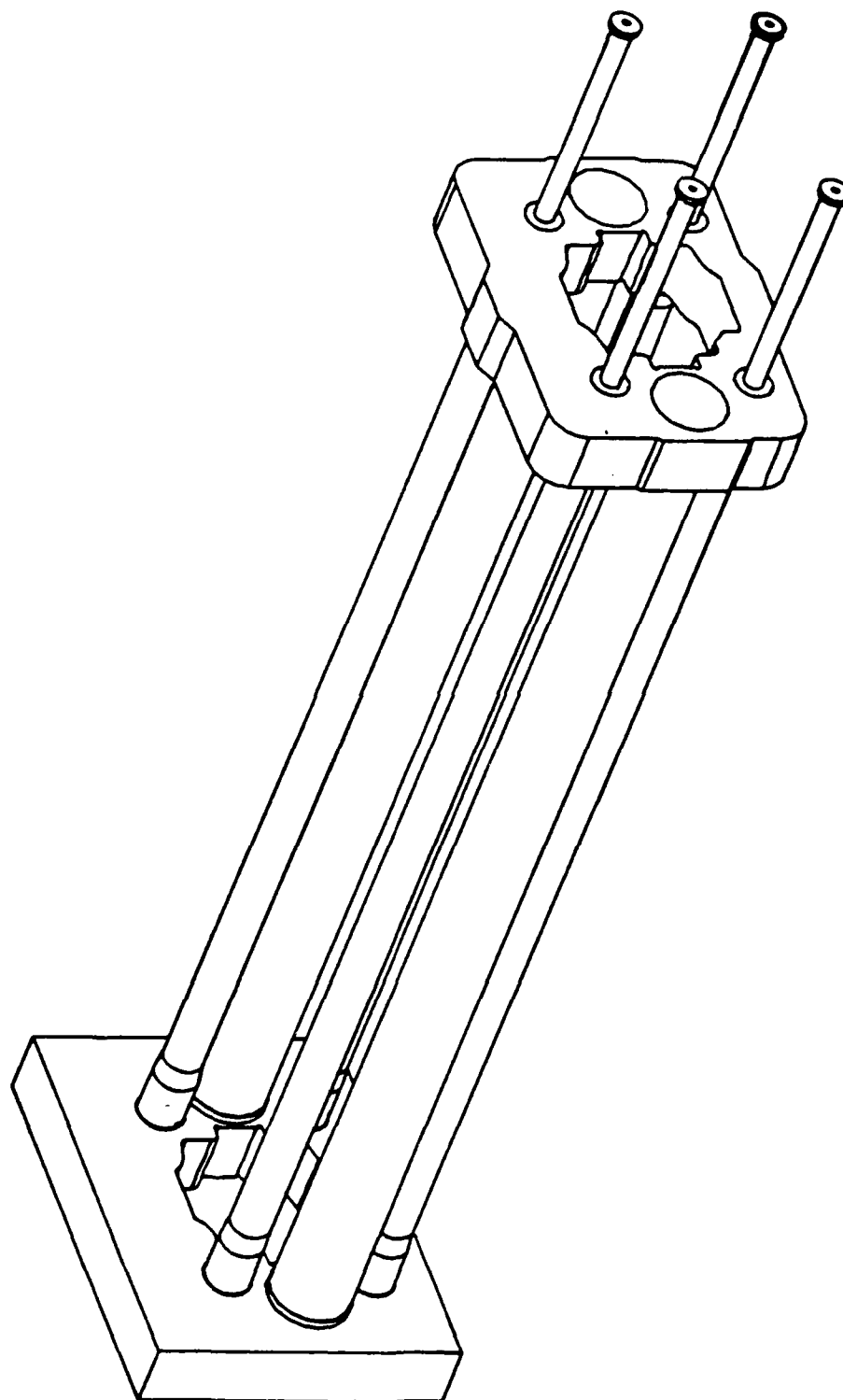
LTHD 11
15 JANUARY 1987
BA 4

FMC



LTHD 12
15 JANUARY 1987
BA 5

FMC



LTHD 13
15 JANUARY 1987
BA 6

FMC

DESIGN CHANGE: RECOIL SYSTEM

SEQUENCE OF EVENTS AND RATIONALE

CONVERT TO SIMPLE ORIFICE WITH HIGH C'RECOIL FORCE

ELIMINATE WEIGHT OF ORIFICE RODS

INCREASE ENERGY RECOVERY

CLOSELY MATCHED CONSTANT MOMENT SAFETY FACTOR CURVE

COMPLICATIONS

COOK OFF FROM LOAD POSITION NECESSITATES SECOND ORIFICE

LARGE PORTION OF ROD PROFILE FROM RECOIL

INCREASES SENSITIVITY TO AMBIENT TEMP FLUCTUATIONS

INCREASES WEIGHT OF COMPONENTS DUE TO OVERPRESSURE SPIKES

EXCESSIVE ENERGY RECOVERY NECESSITATES HIGH FLOW BLOW-OFF VALVES

SITUATION ANALYSIS

WEIGHT PENALTY OF COMPLICATIONS EXCEEDS BENEFIT

ENERGY RECOVERY INCREASE WITH ZONE 3 NEGLIGIBLE

(DUE TO HIGH C'RECOIL FORCE AND RESULTANT SHORTER RECOIL)

FURTHER STABILITY ANALYSIS INDICATES EARLY SPIKES REDUCE HOP

DECISION

EMPLOY TRADITIONAL ORIFICE RODS

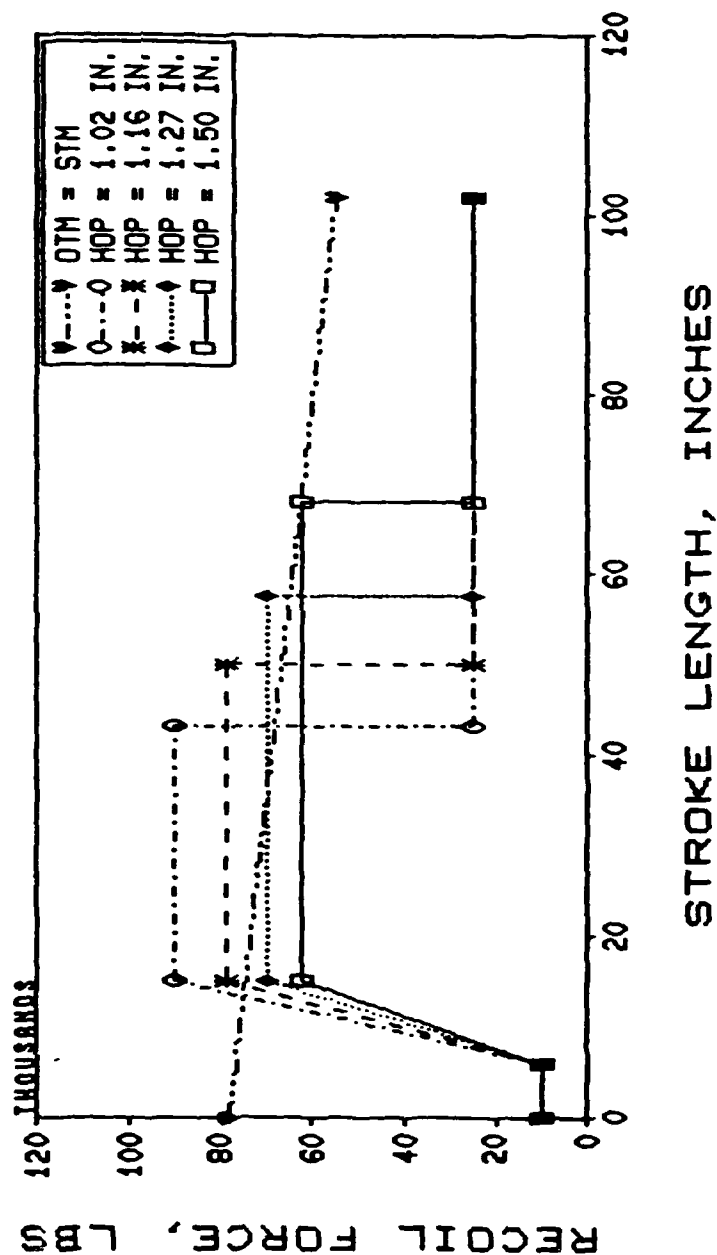
LTHD 14

15 JANUARY 1987

BA 7

FMC

EFFECT OF RECOIL FORCE PROFILE ON HOP K OF TRAILS = 3000 LB/IN EA



LTHD 15
15 JANUARY 1987
BA 8

Technical drawing of a muzzle brake casting, showing four views: View C-C, Section B-B, Partial Section A-A, and a front view. The drawing includes dimensions in inches and millimeters, material specifications, and a title block.

VIEW C-C

Typical CRITICAL AREA (SEE NOTE 1)

SECTION B-B

PARTIAL SECTION A-A

FRONT VIEW

TITLE BLOCK:

1. 12-05/55/A

2. 12-05/55/A

3. 12-05/55/A

4. 12-05/55/A

5. 12-05/55/A

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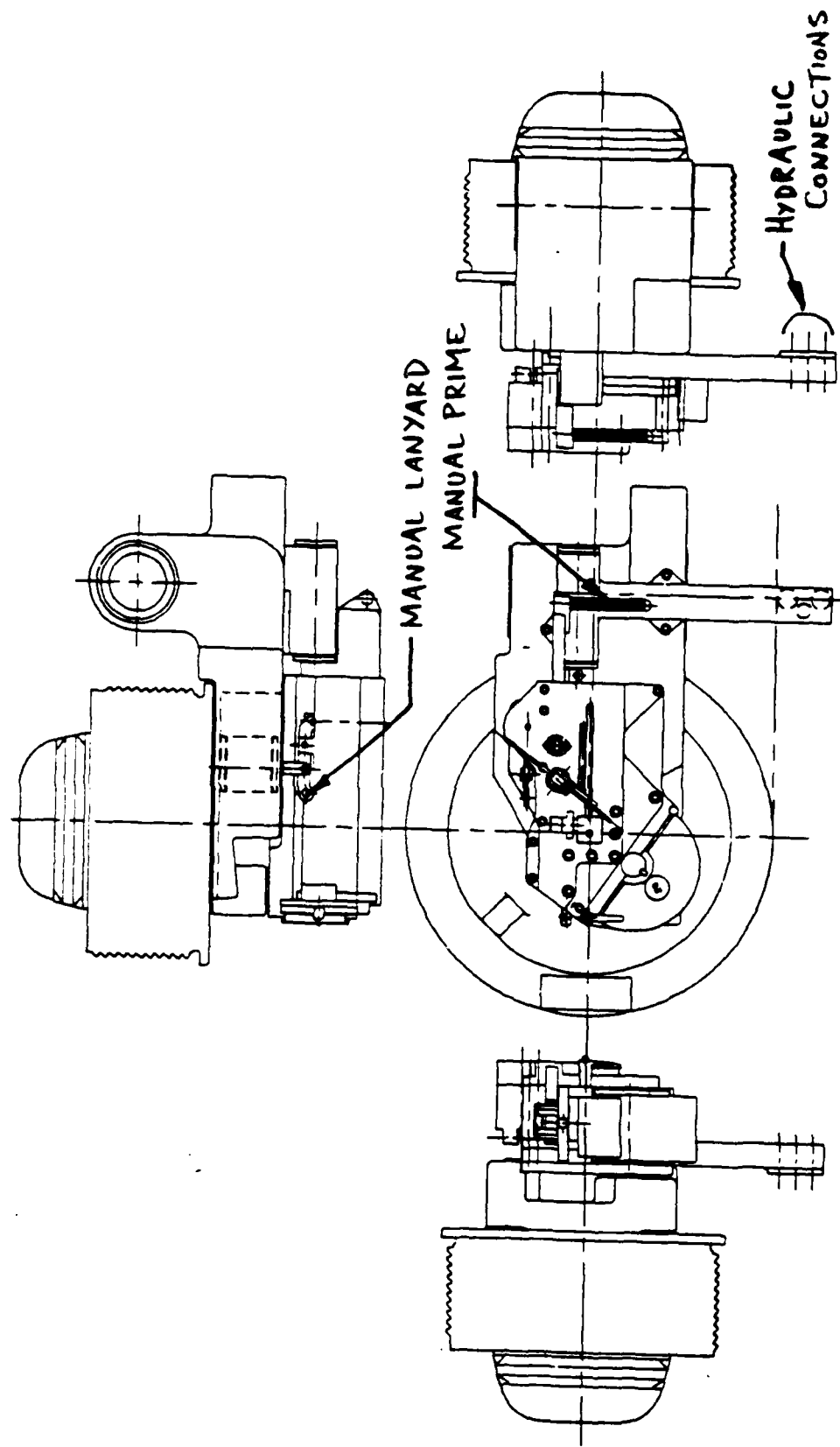
199. 12-05/55/A

200. 12-05/55/A

201. 12-05/55/A</

16

FMC



LTHD 17

15 JANUARY 1987

BA 10

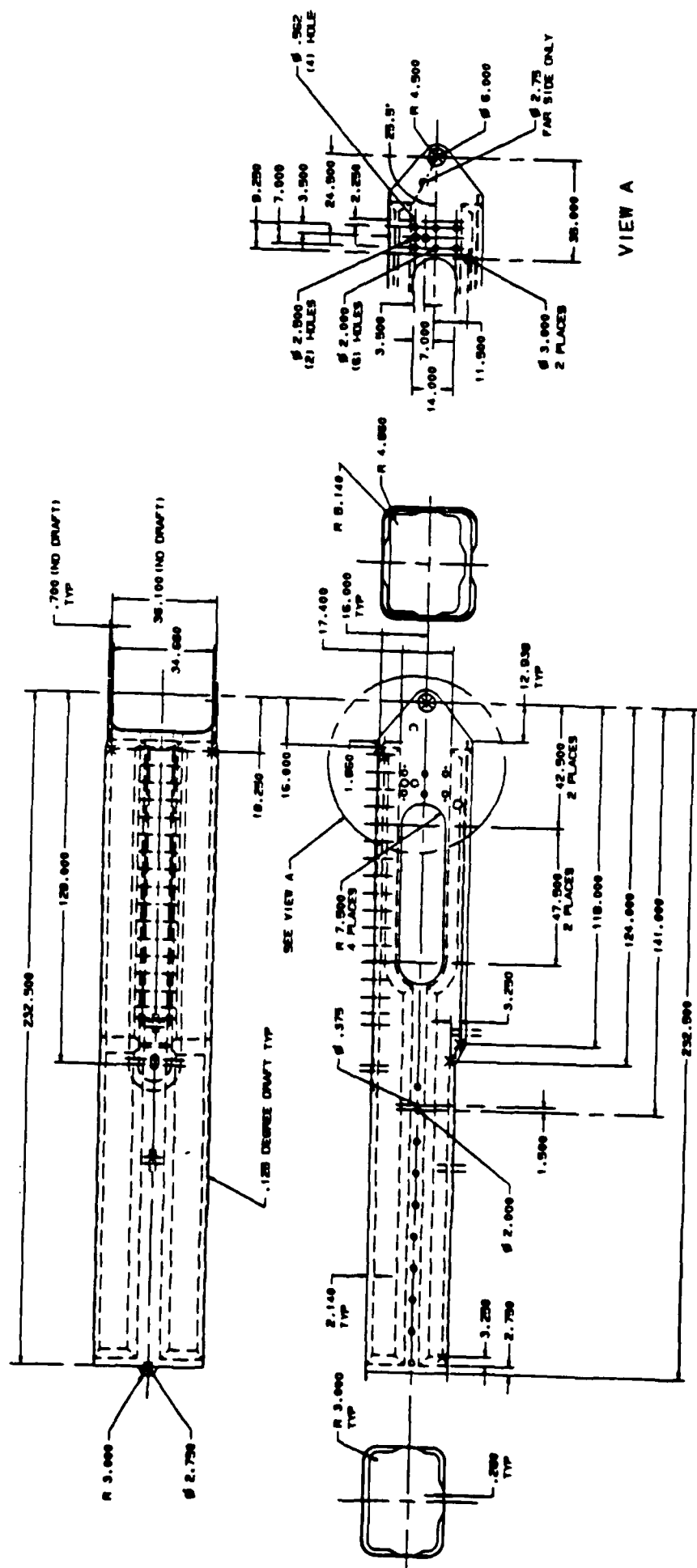
PRIMER Auto Loader NOT FUNDED UNDER CONTRACT

LTHD 18
15 JANUARY 1987
BA 11

LTWD 18

15 JANUARY 1987

BA "

18
31

FMC

DESIGN CHANGE: ELEVATION CYLINDER LOCATION

SEQUENCE OF EVENTS AND RATIONALE

EMPLOY DUAL CYLINDERS ON SIDES OF CRADLE

REDUNDANT

RESISTANT TO HI G LOADS FROM LAPES

GEOMETRY FACILITATES RELATIVELY CONSTANT TORQUE ARM

COMPLICATIONS

POOR RESOLUTION OF QE IS ANTICIPATED DUE TO SMALL TORQUE ARM

SITUATION ANALYSIS

ALTERNATIVE HIGH TORQUE ARM GEOMETRY IS DETERMINED (ABOVE CRADLE)

SINGLE ACTUATOR IS EMPLOYED TO MINIMIZE WEIGHT

BASELINE AND ALTERNATIVE HAVE EQUIVALENT NATURAL FREQUENCIES

ALTERNATIVE (DUE TO MORE LEVERAGE) IS 40% AS SENSITIVE TO

BEARING LASH AND BREAK-AWAY - OVERSHOOT

ALTERNATIVE CAN PROBABLY BE MADE TO RESIST LAPES G-LOADING

ALTERNATIVE TORQUE ARM IS NOT AS CONSTANT - INCREASING ENERGY

CONSUMPTION

ALTERNATIVE GEOMETRY HAS A BROAD RANGE OF FEASIBLE LOCATIONS

BASELINE GEOMETRY HAS A NARROW BAND OF FEASIBLE LOCATIONS

DECISION

SWITCH TO ALTERNATIVE FOR IMPROVED RESOLUTION AND MOUNTING

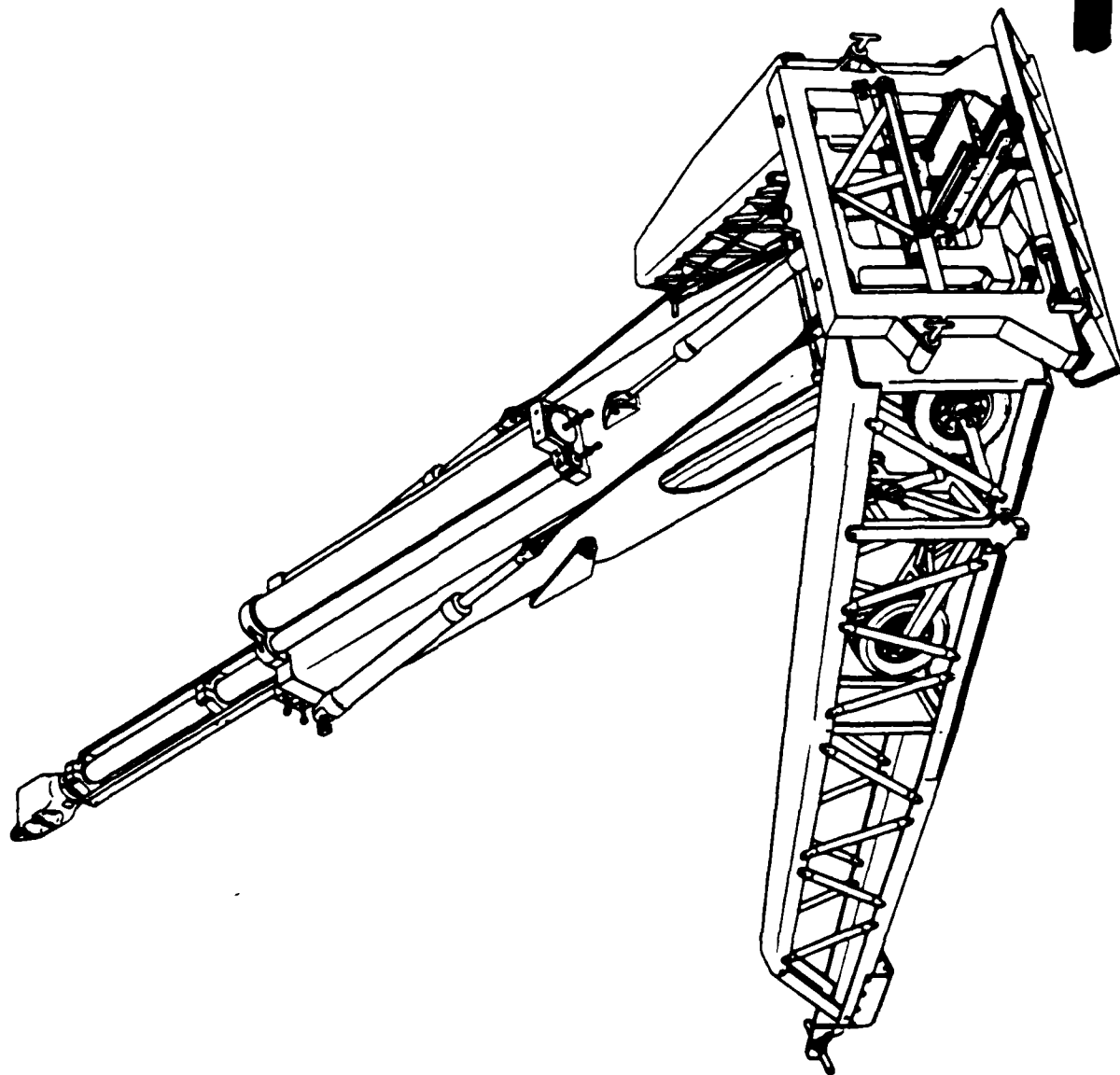
POINT FLEXIBILITY

LTHD 19

15 JANUARY 1987

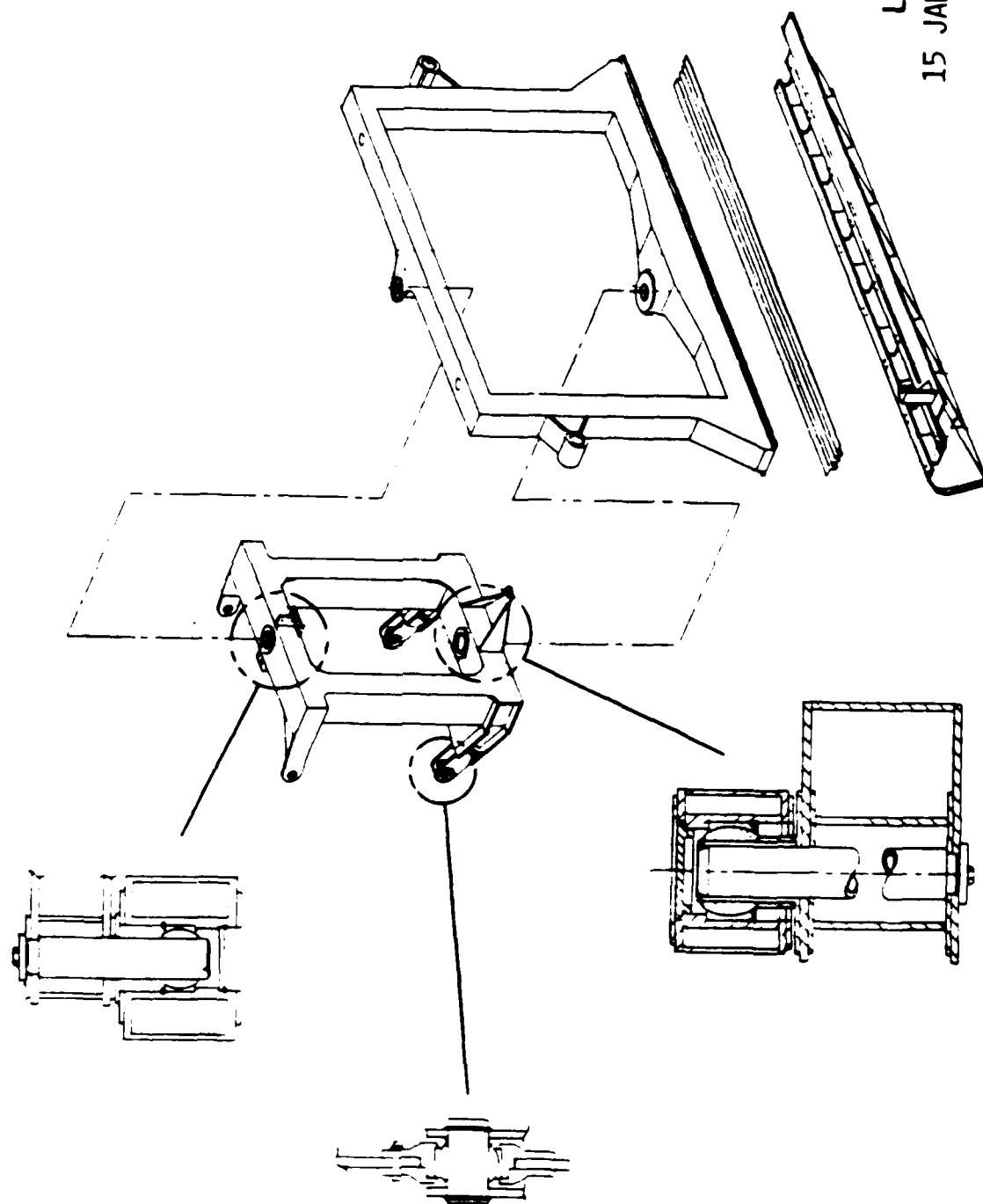
BA 12

FMC



LTHD 20
15 JANUARY 1987
BA 13

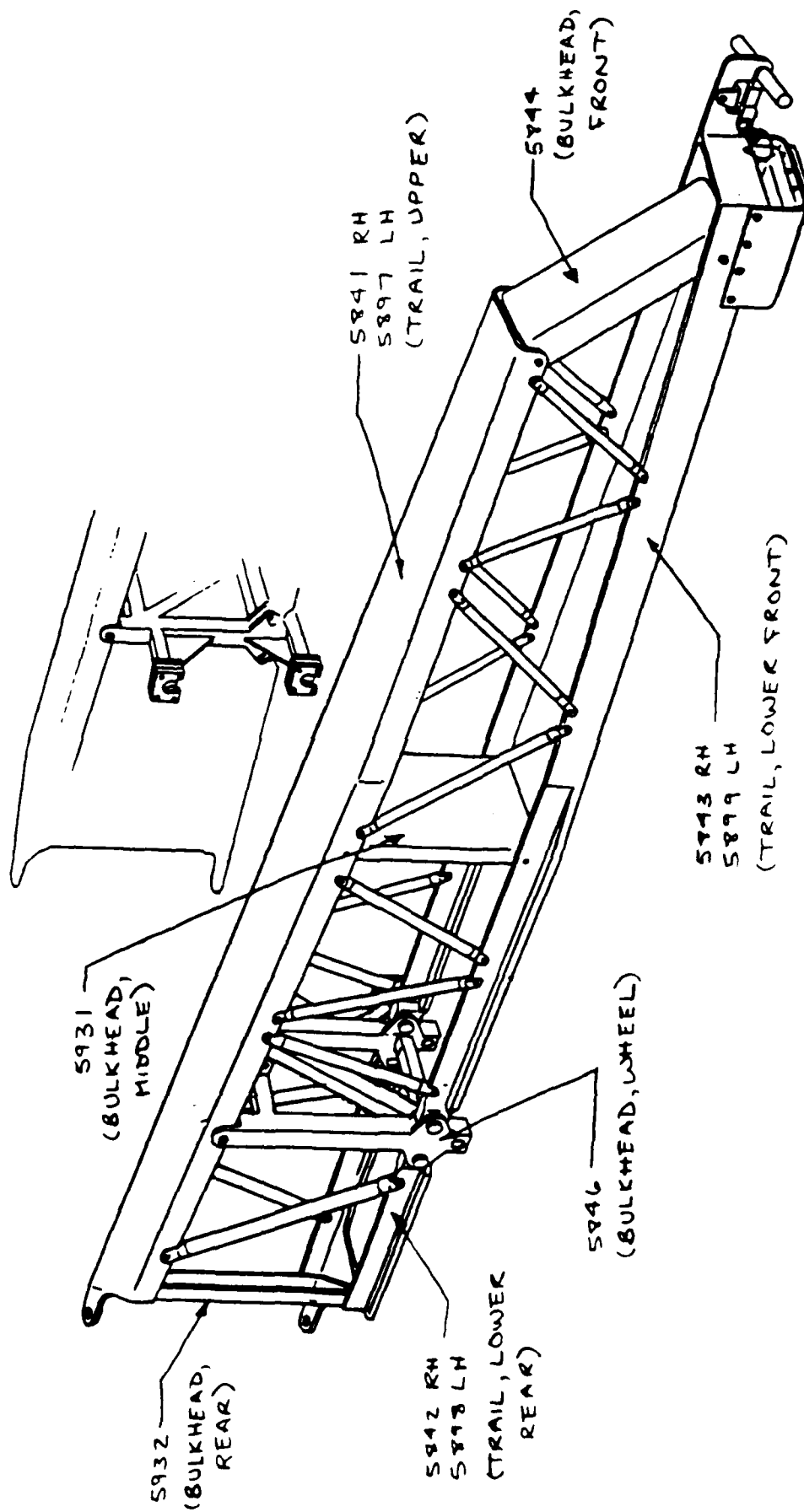
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LTHD 21
15 JANUARY 1987
BA 14

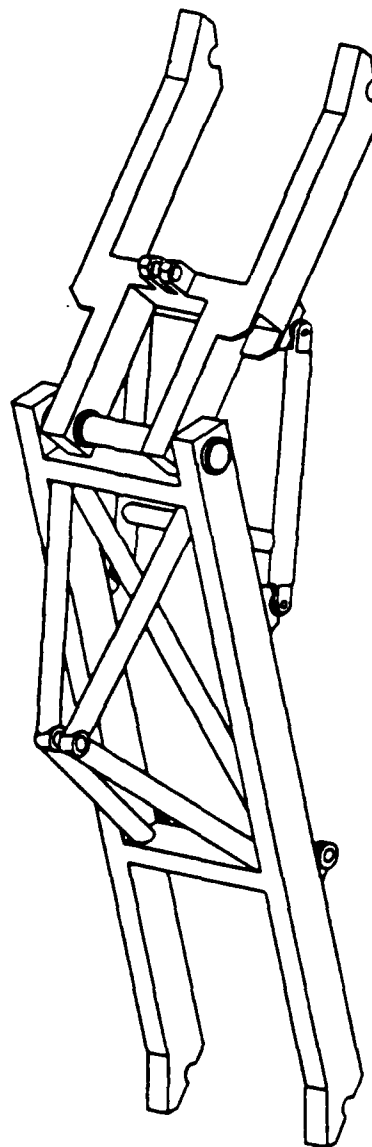
21

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LTHD 22
15 JANUARY 1987
BA 15

FMC



LTHD 23
15 JANUARY 1987
BA 16

FMC

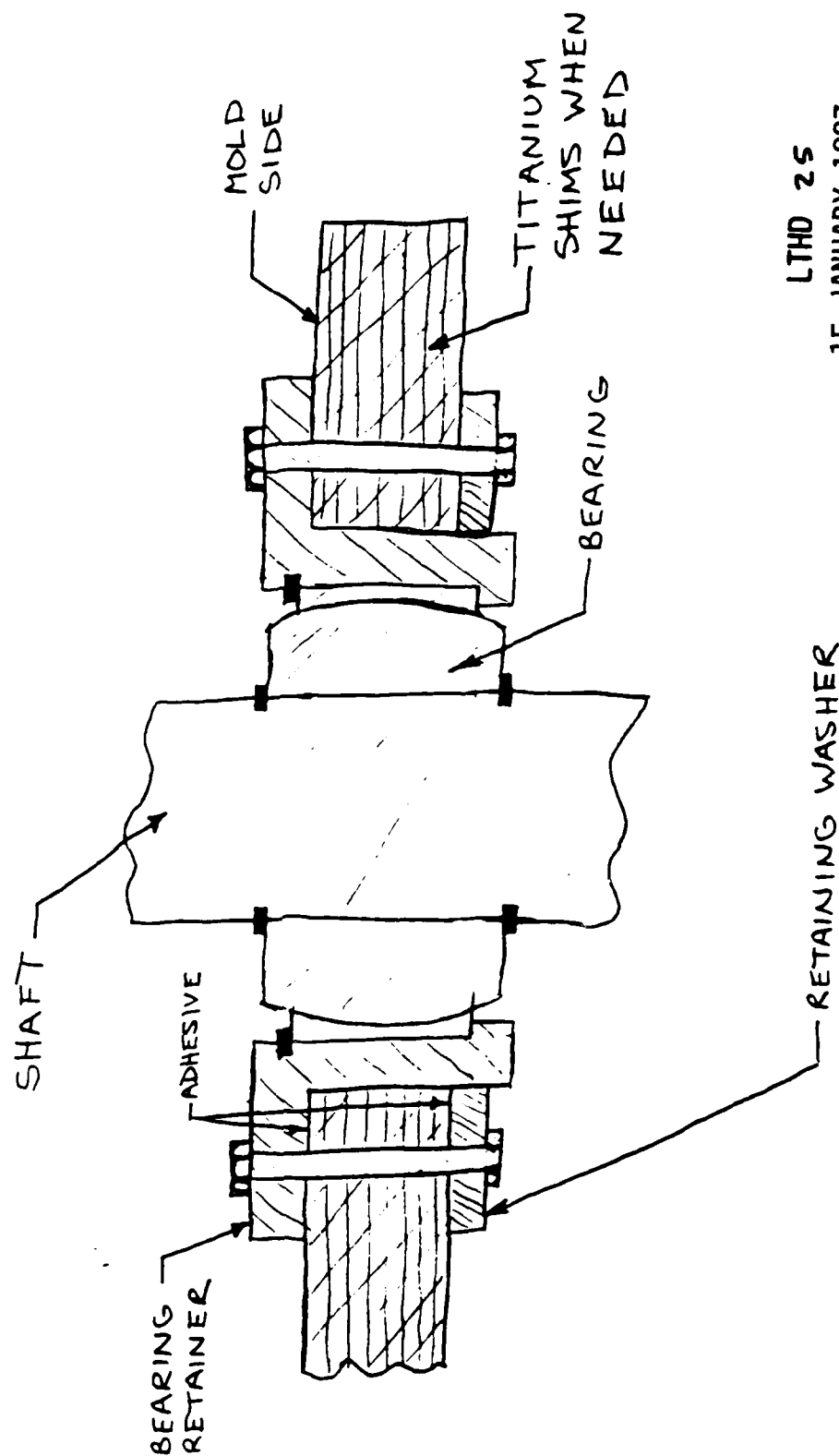
ASSEMBLY SEQUENCE &

INTERFACE DETAILS

LTHD 24
15 JANUARY 1987
BA 17

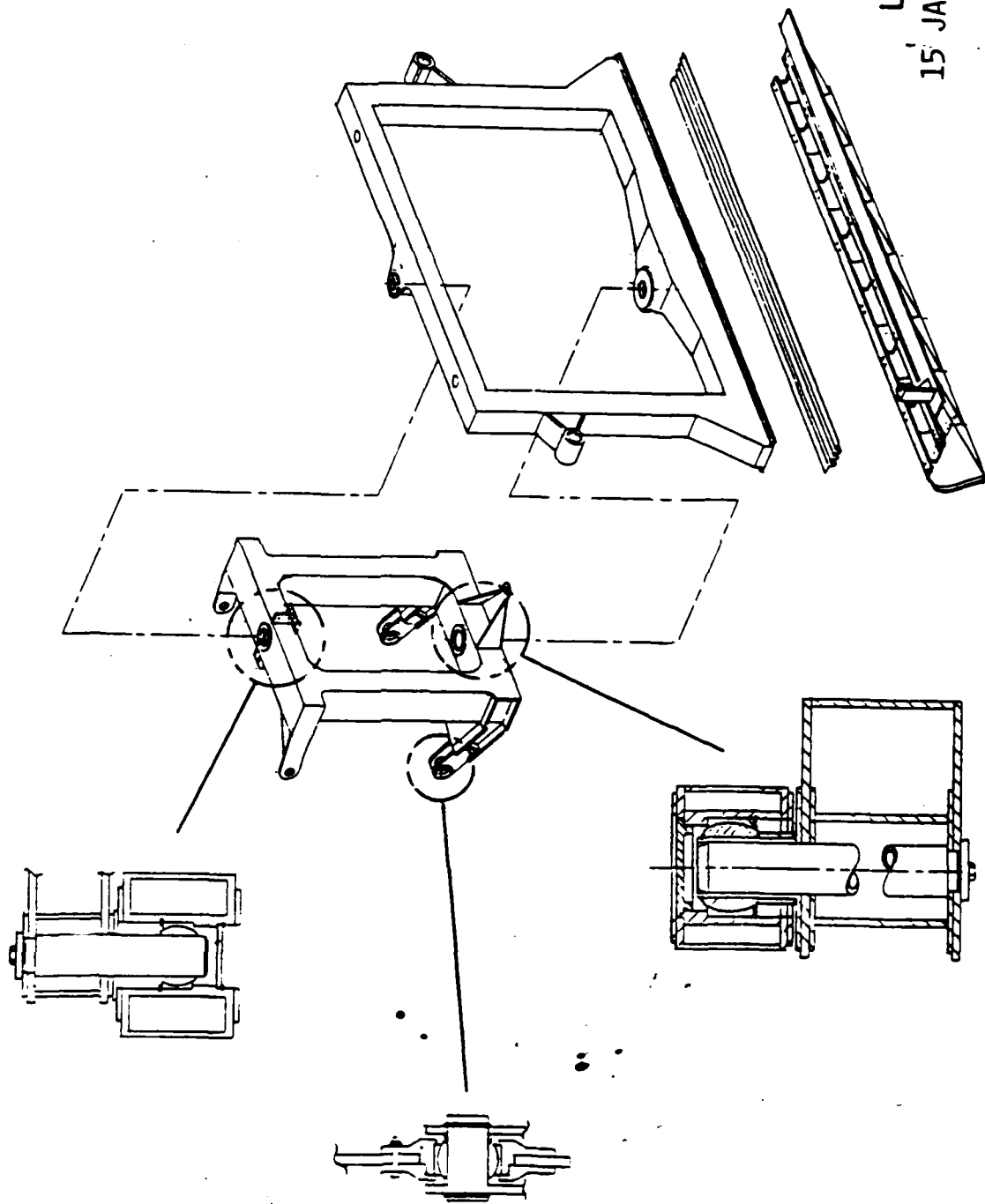
24

FMC



LTHD 25
15 JANUARY 1987
BA 18

FMC



LTHD 26
15 JANUARY 1987
BA 19

FMC

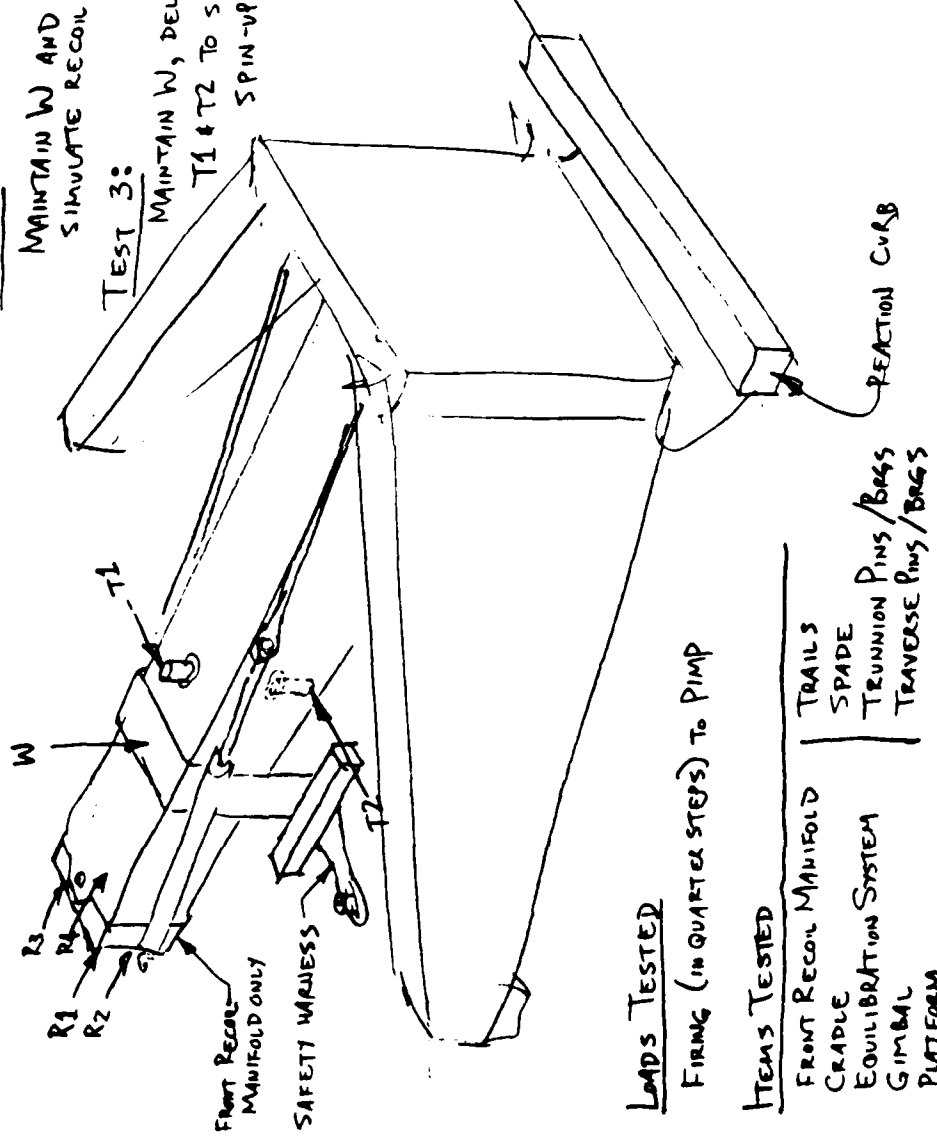
TEST 1: Apply W to SIMULATE DEAD WEIGHT LOAD.

TEST 2:

MAINTAIN W AND ADD R1-R4 TO
SIMULATE RECOIL FORCES.

TEST 3:

MAINTAIN W, DELETE R1-R4, AND ADD
T1 & T2 TO SIMULATE PROJECTIVE
SPIN-UP TORQUES.



LOADS TESTED

FIRING (IN QUARTER STEPS) TO PIMP

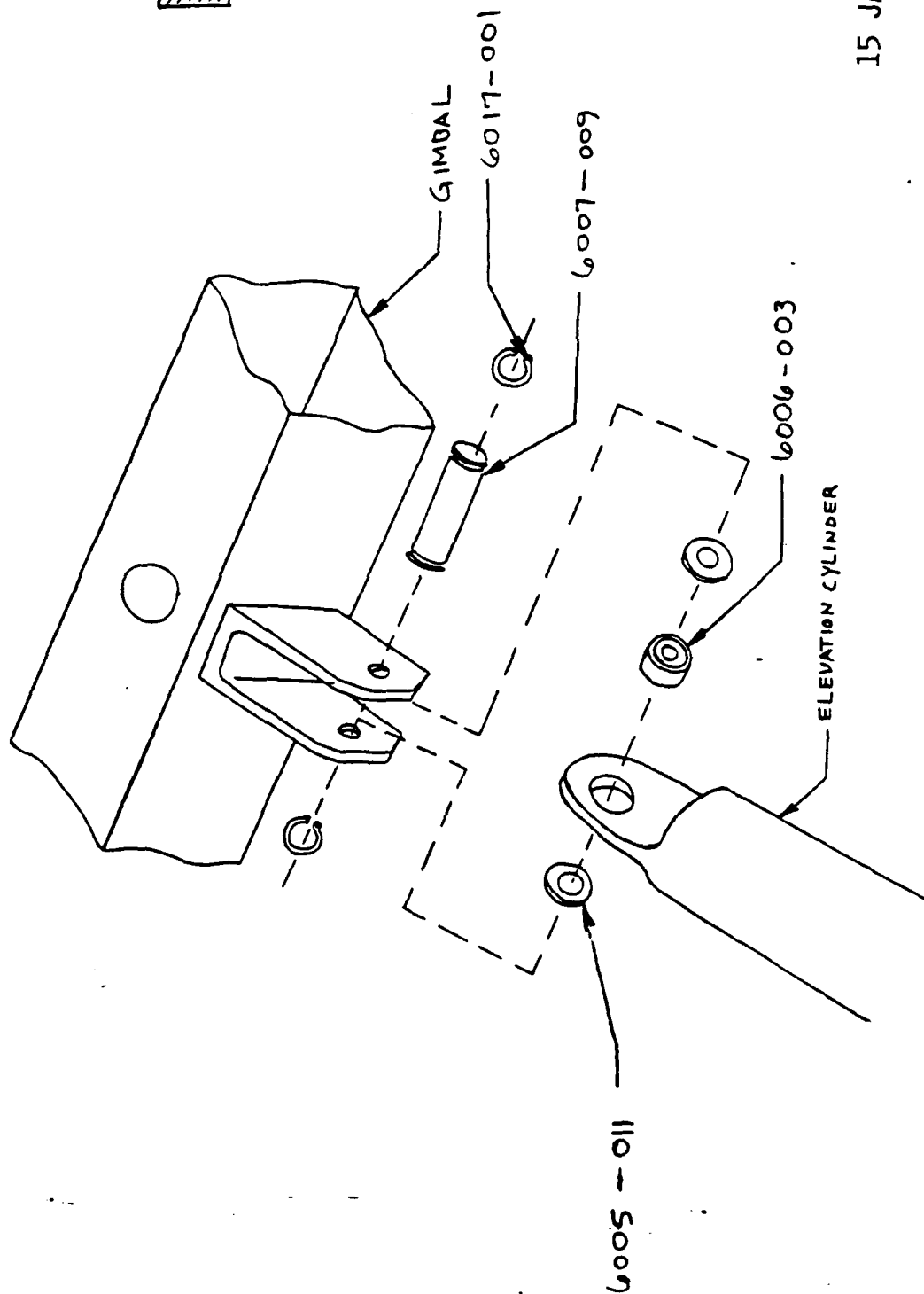
ITEMS TESTED

FRONT RECOIL MANIFOLD
CRADLE
EQUILIBRATION SYSTEM
GIMBAL
PLATFORM

TRAILS
SPADE
TRUSSION PINS/BAGS
TRAVERSE PINS/BAGS

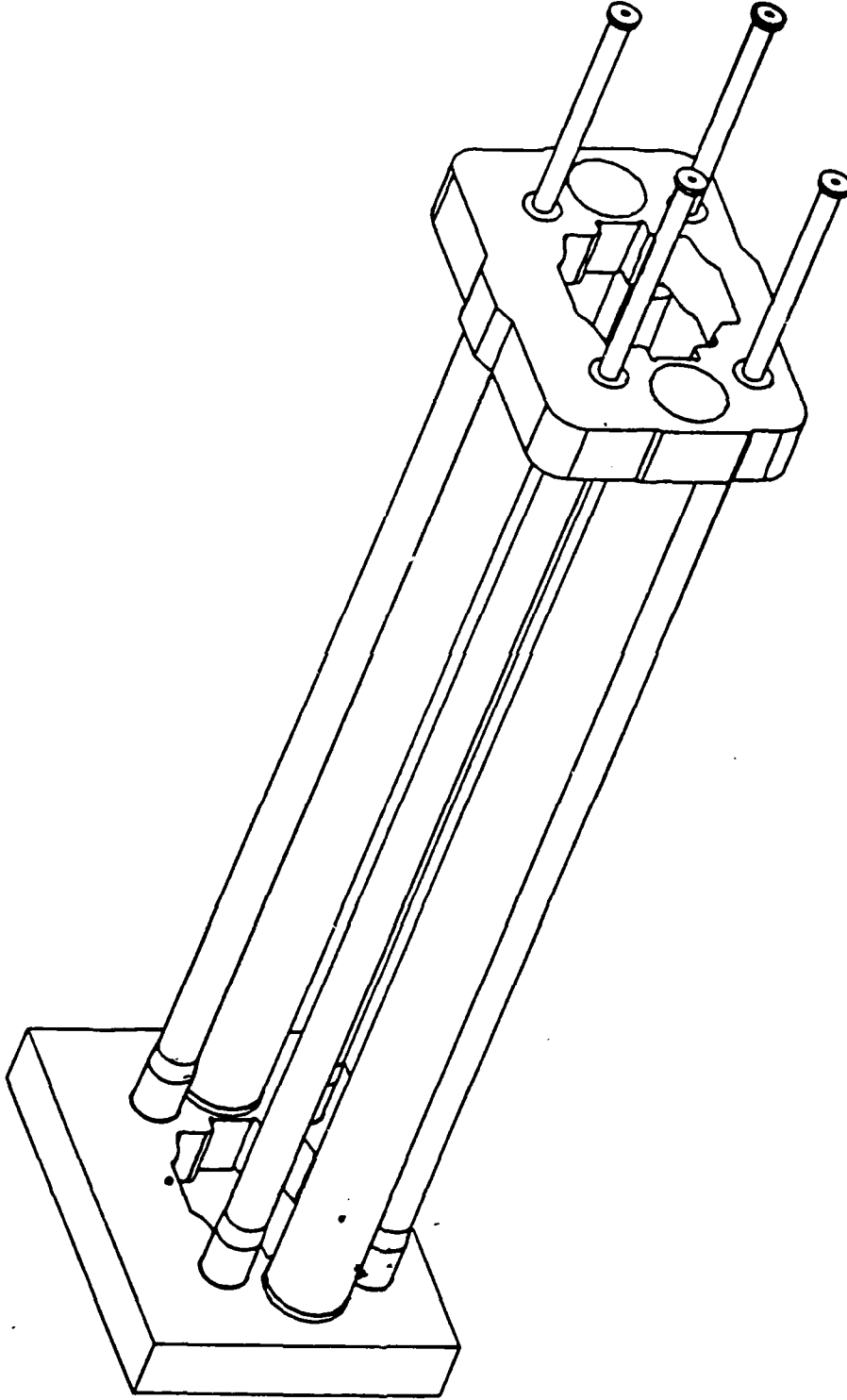
LTHD 27
15 JANUARY 1987
BA 20

FMC



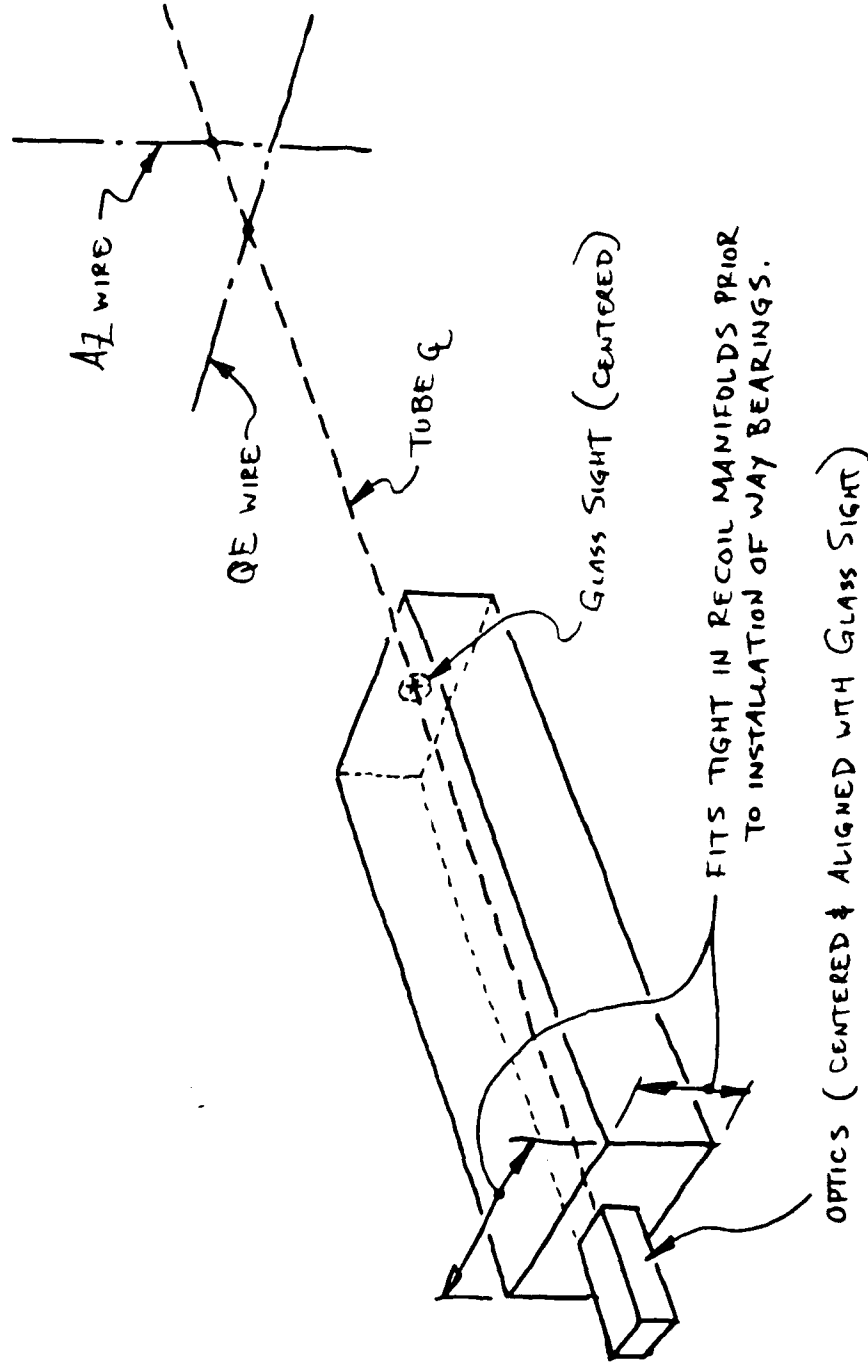
LTHD 20
15 JANUARY 1987
BA 21

FMC



LTHD 29
15 JANUARY 1987
BA 22

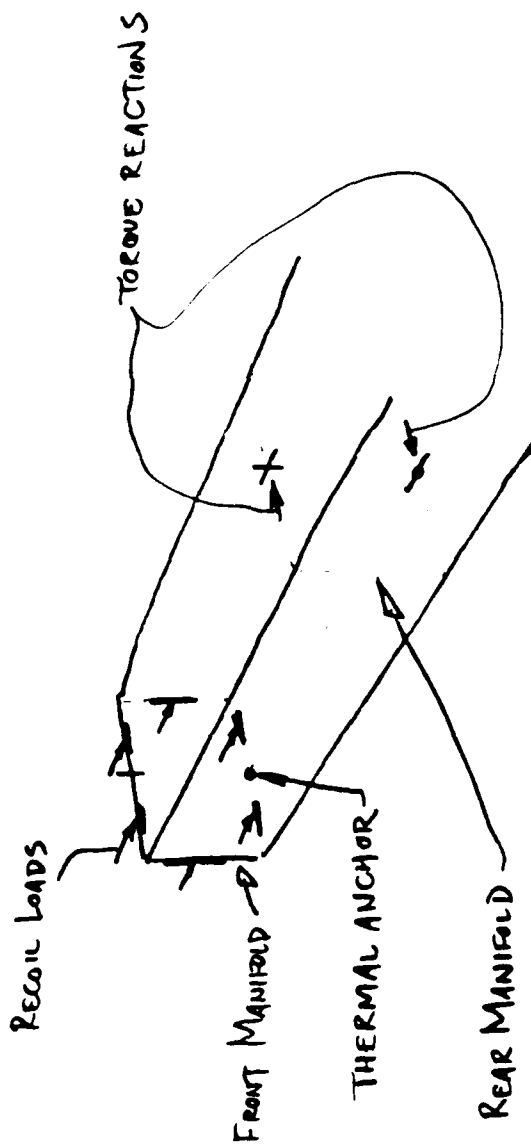
FMC



LTHD 30
15 JANUARY 1987
BA 23

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FMC



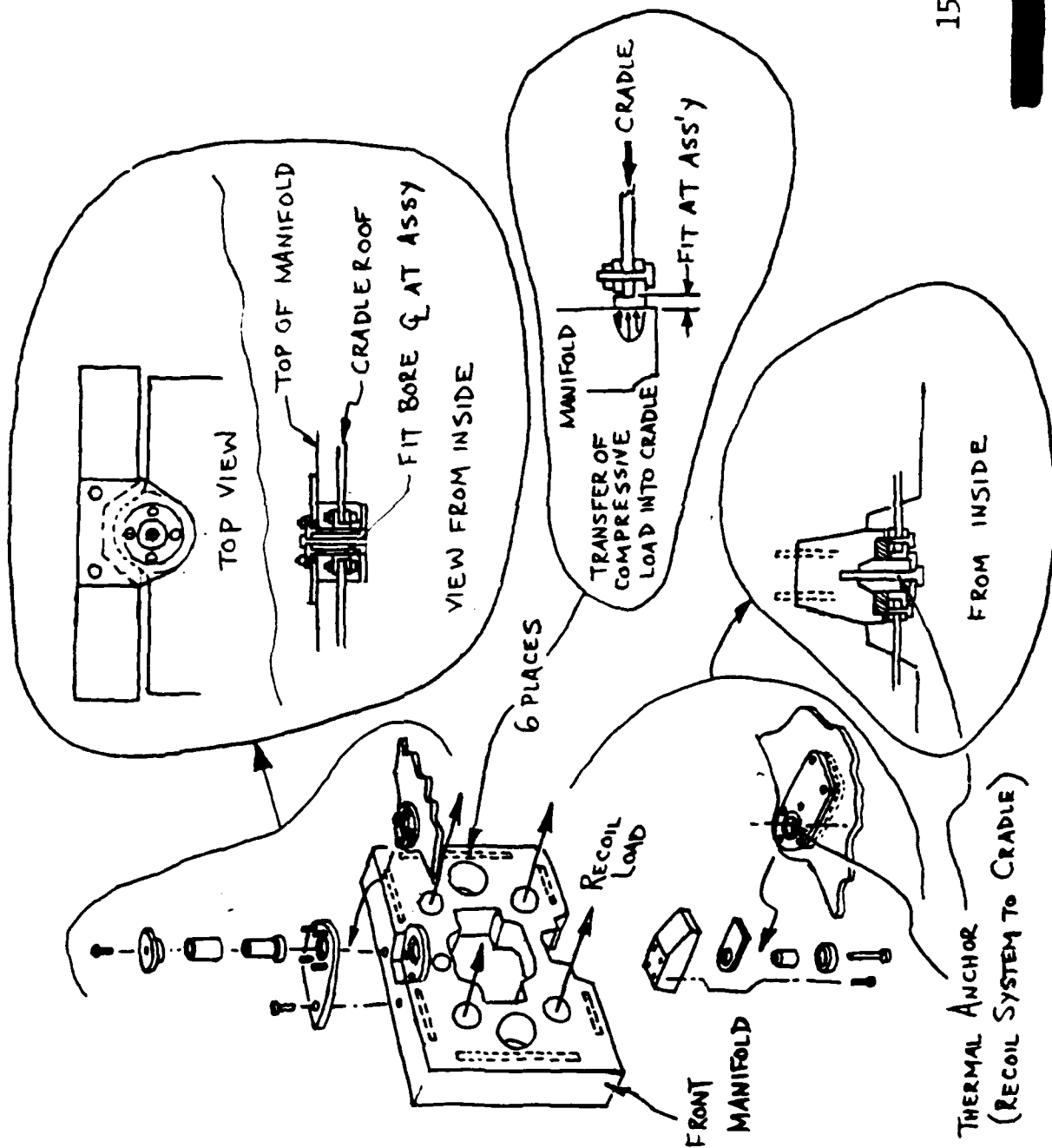
LTHD 31

15 JANUARY 1987

BA 24

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FMC

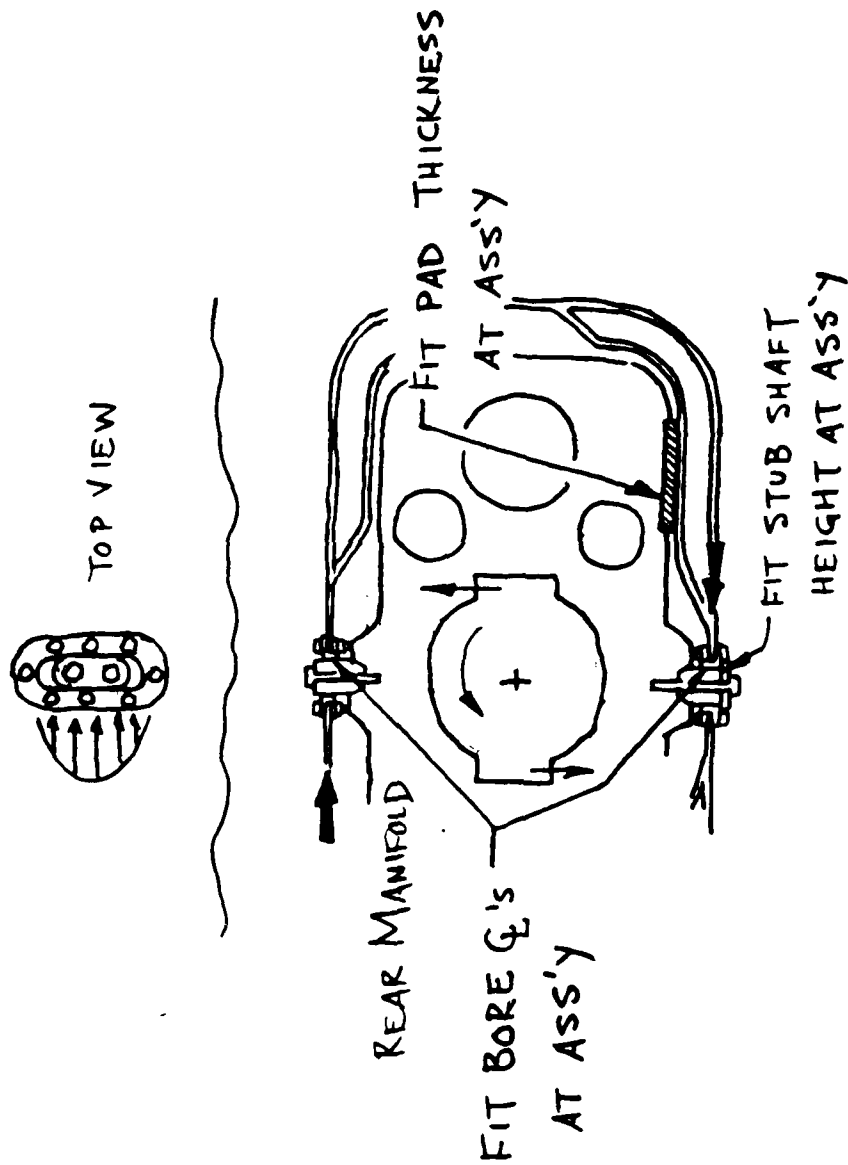


LTHD 32
15 JANUARY 1987
BA 25

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FMC

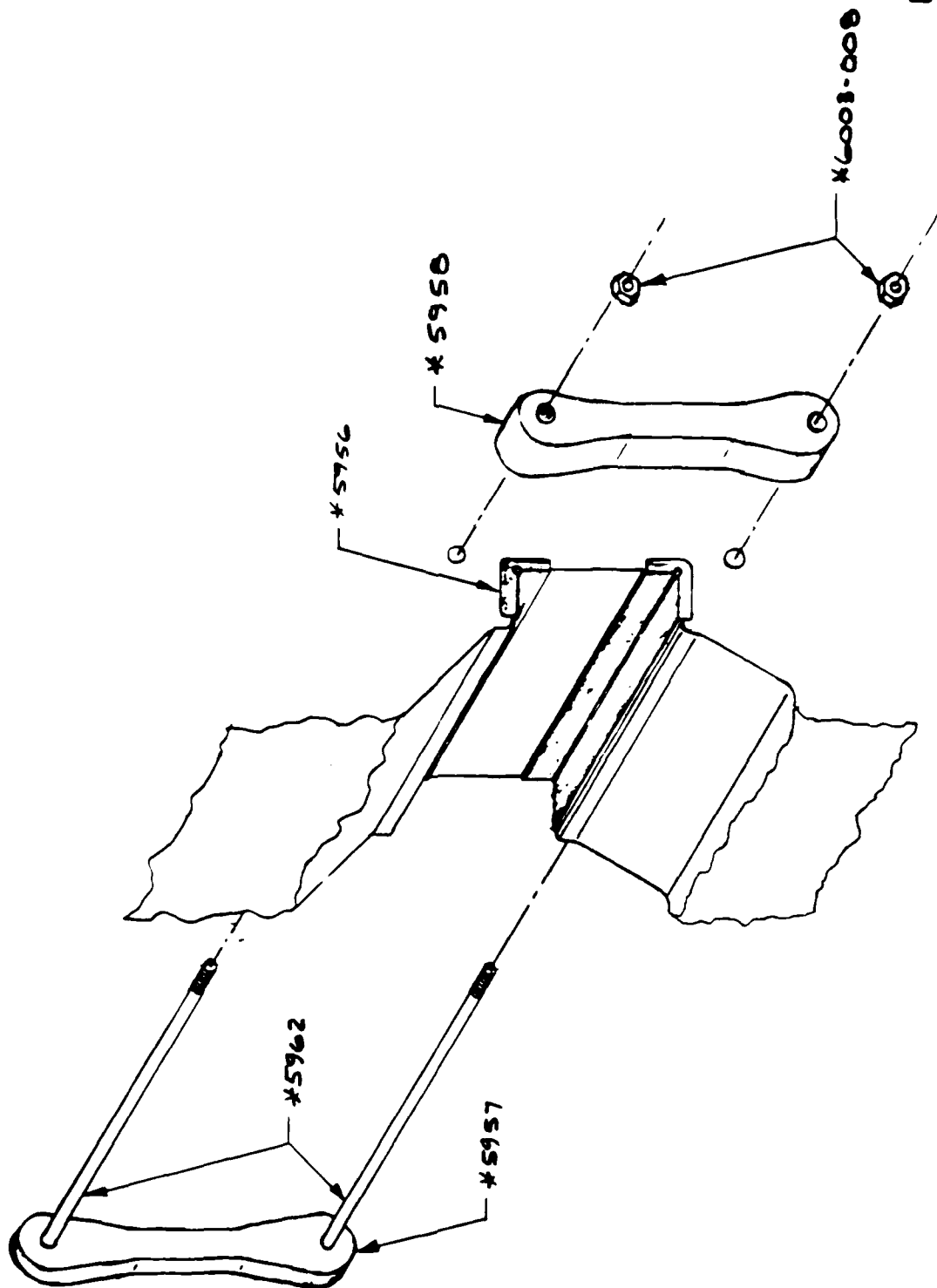


LTHD 33
15 JANUARY 1987
BA 26

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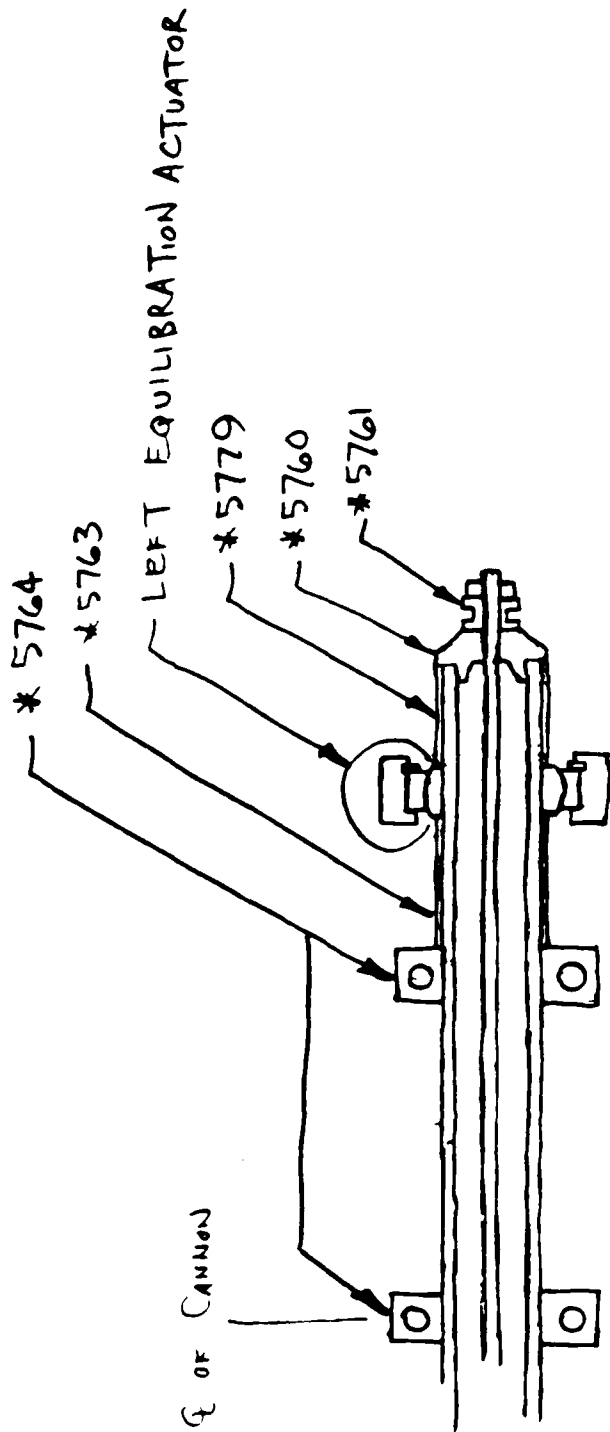
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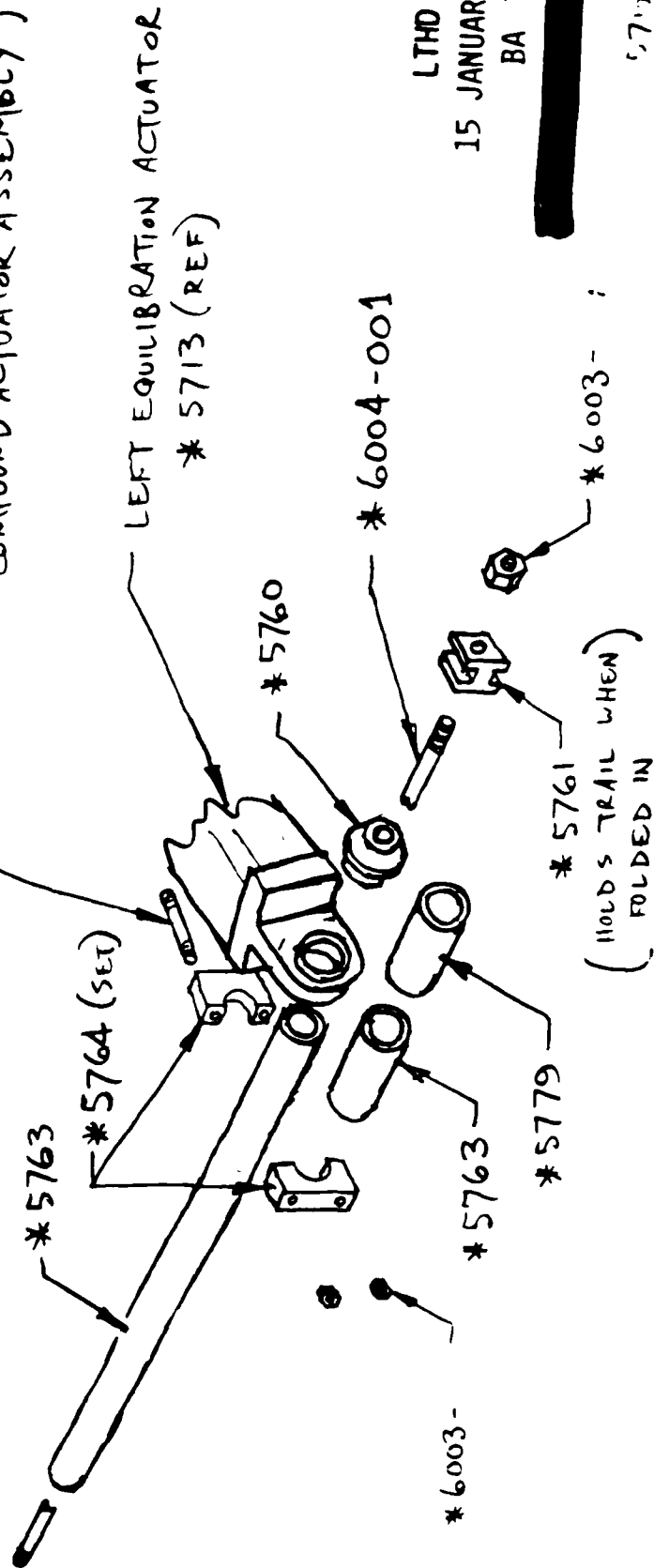
LTHD 34
15 JANUARY 1987
BA 27

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FMC



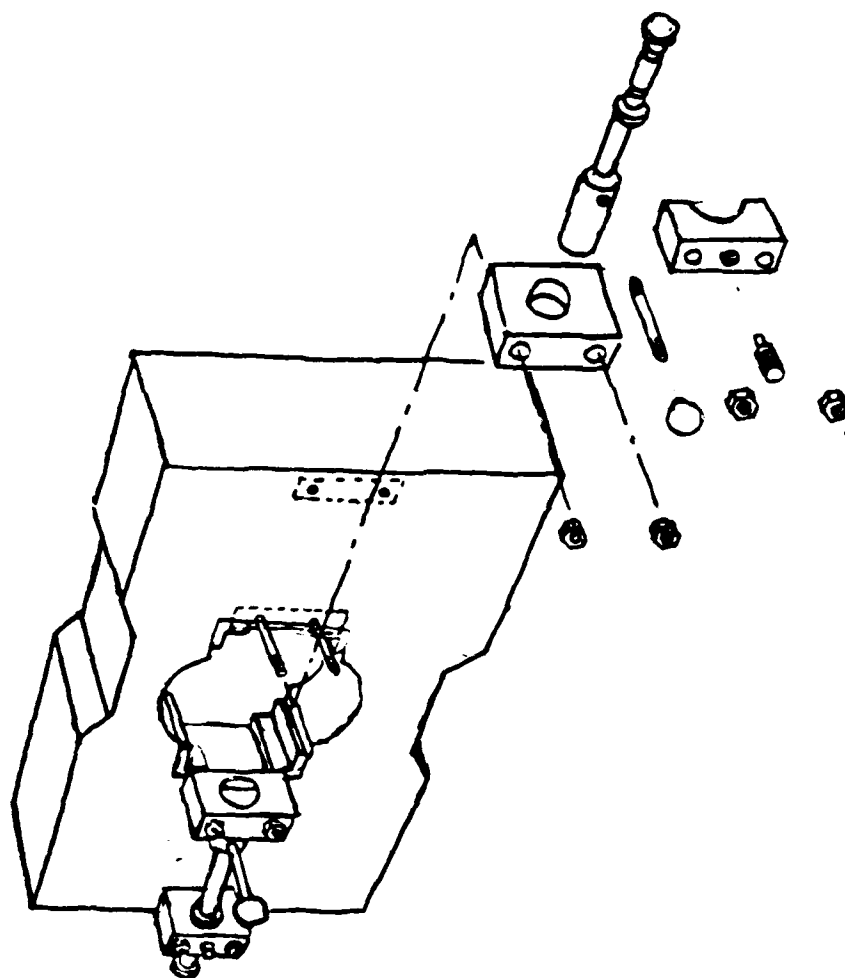
6004-002 (FASTENS INTO FRONT MANIFOLD OF COMPOUND ACTUATOR ASSEMBLY)



LTHD 35
15 JANUARY 1987
BA 28

5713 1/1 35

FMC

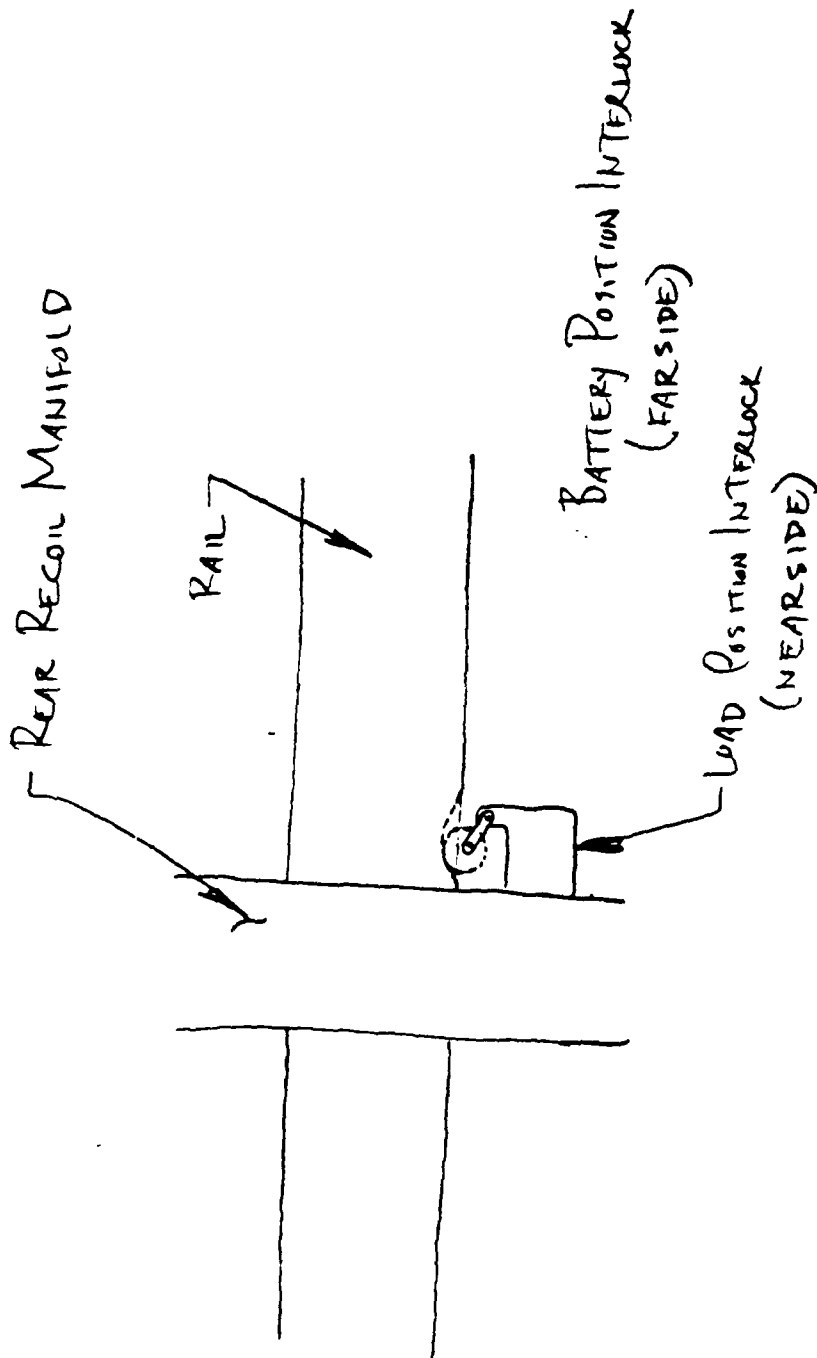


LTHD 36
15 JANUARY 1987
BA 27

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FMC

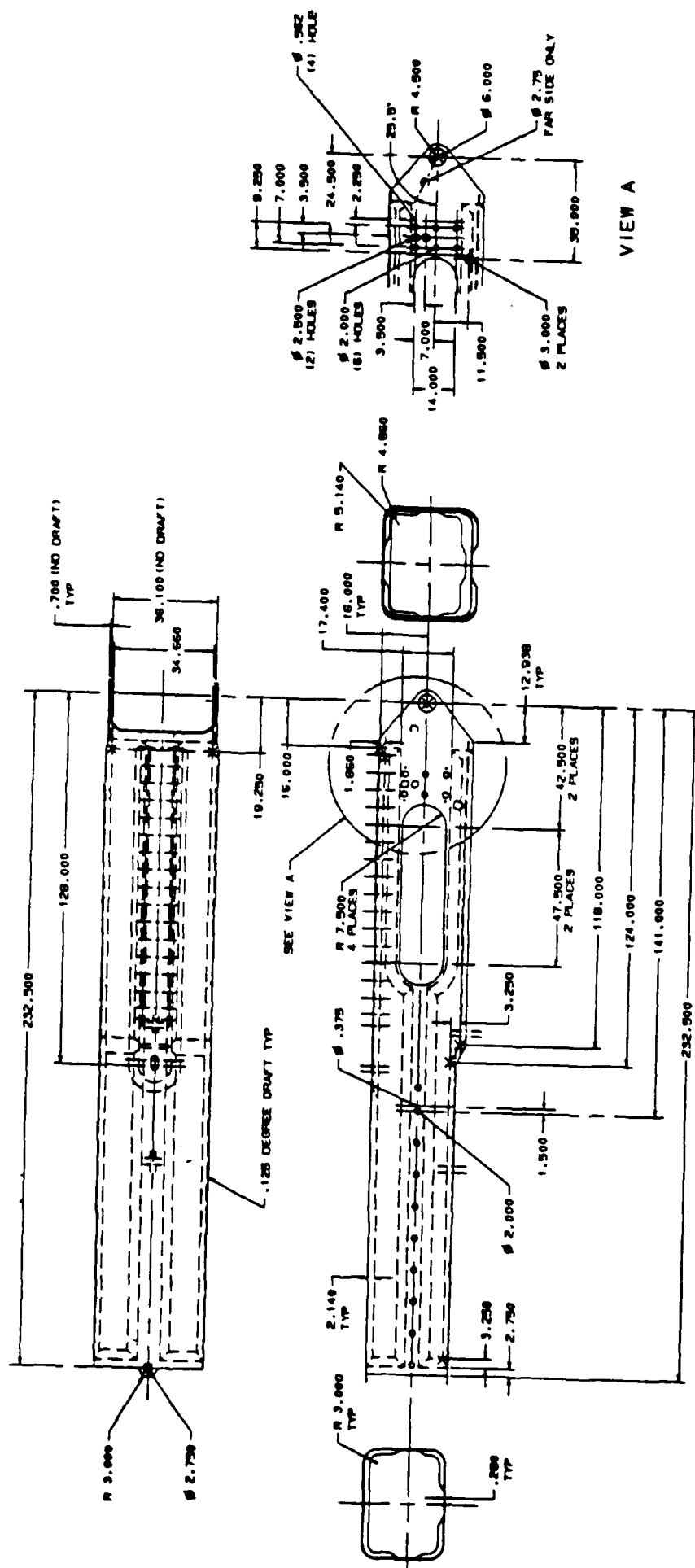
CANNON POSITION INDICATORS



L7ND 37
15 JANUARY 1987
BA 30

LTHD 38
15 JANUARY 1987
BA 31

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AD-A183 984

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87
FMC-E-3041-VOL-B-PT-2 DAAA21-86-C-0047

3/4

UNCLASSIFIED

F/G 19/6

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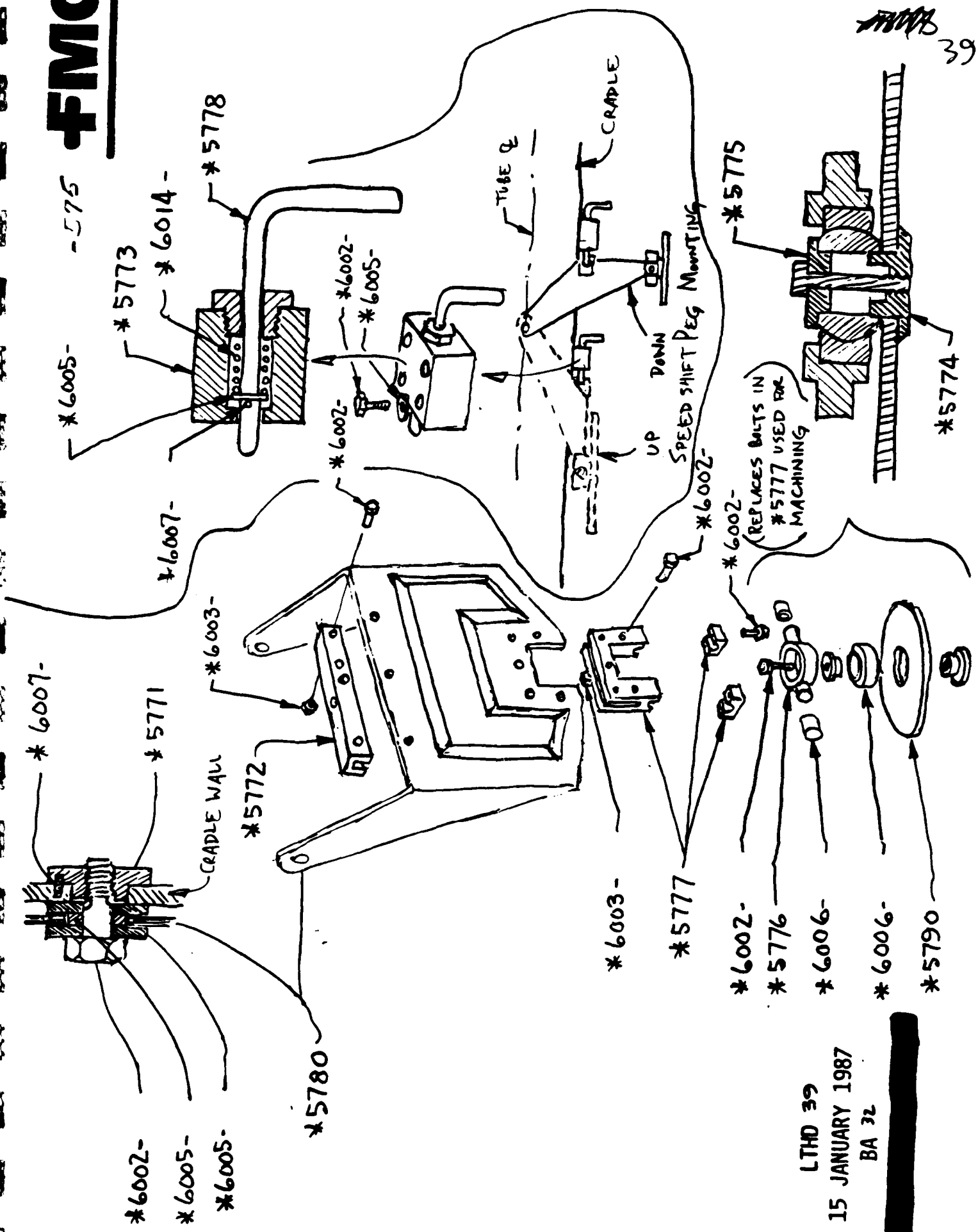


MICROCOPY RESOLUTION TEST CHART

FMC

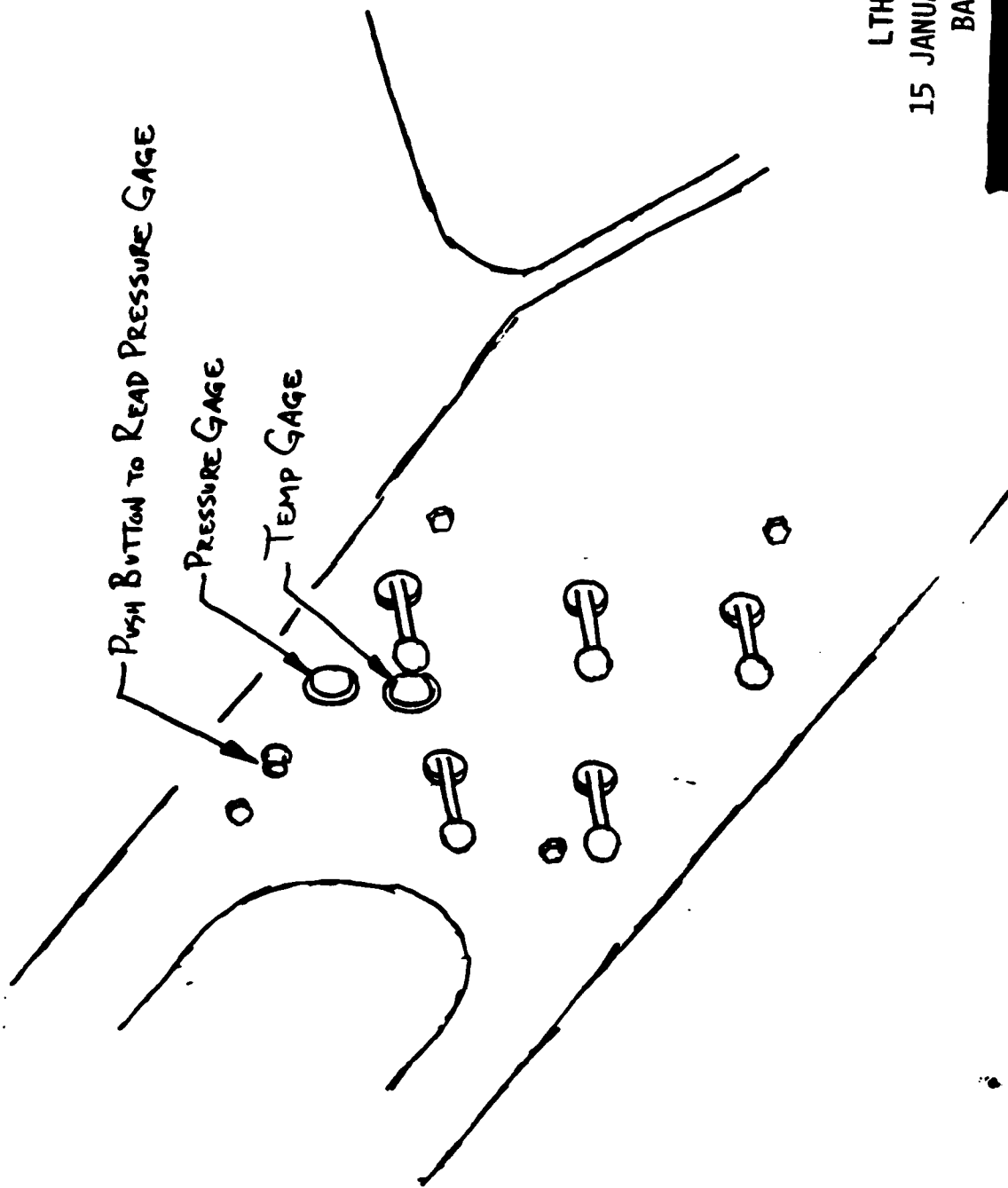
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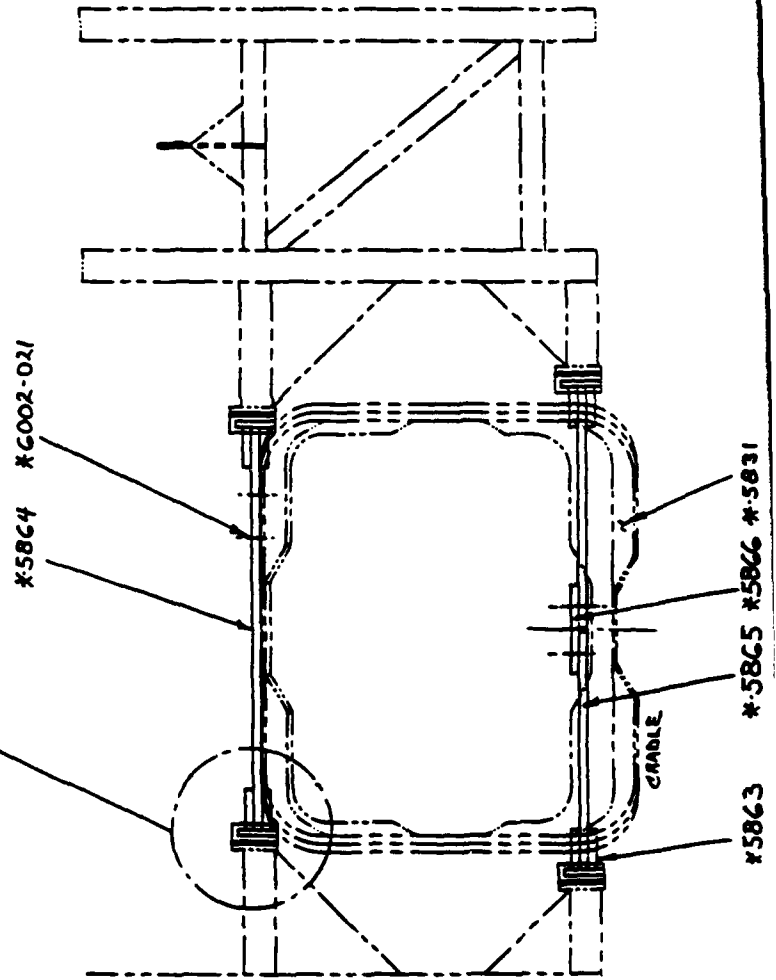
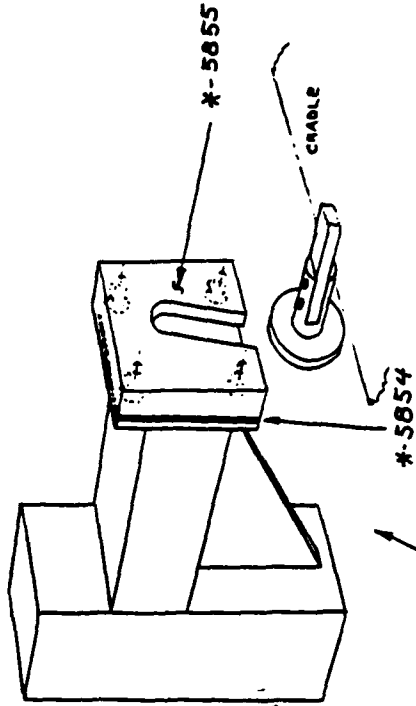
LTHD 39
15 JANUARY 1987
BA 32

FMC



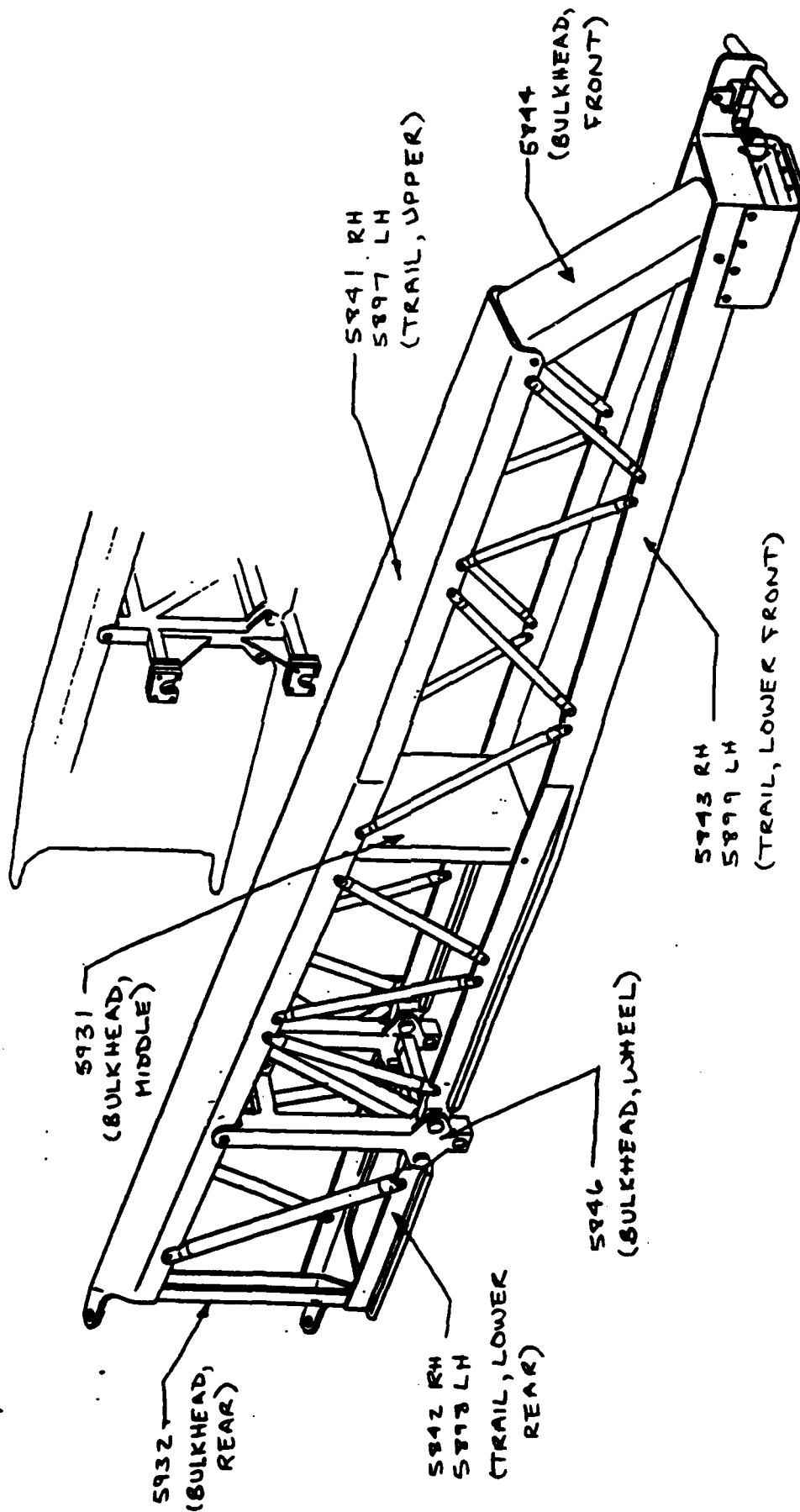
LTHD 40
15 JANUARY 1987
BA 33

FMC



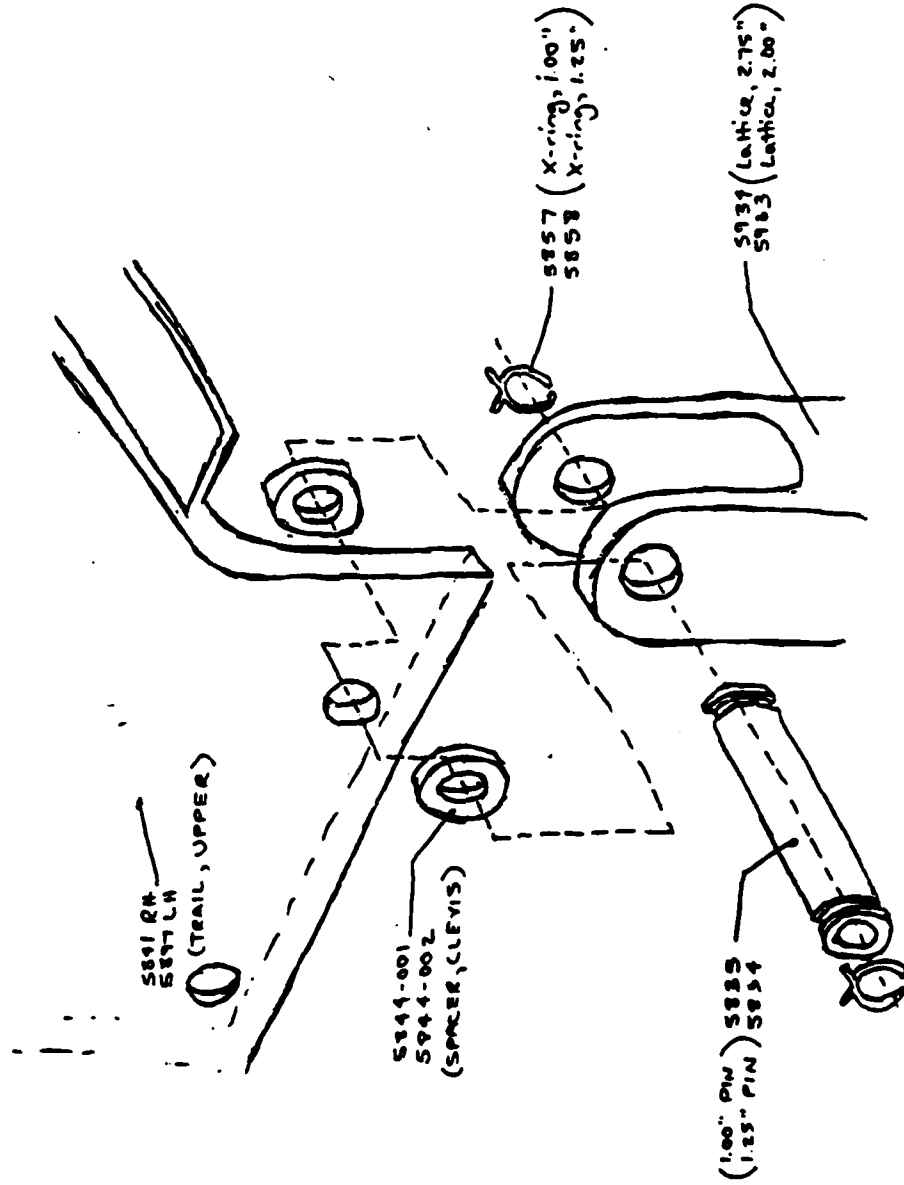
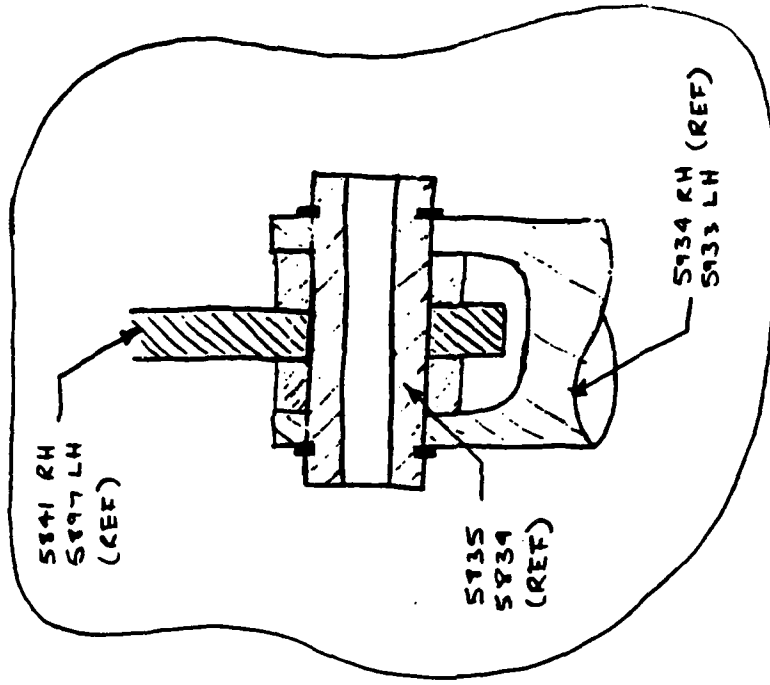
LTHD 41
15 JANUARY 1987
BA 34

FMC



LTHD 42
15 JANUARY 1987
BA 35

FMC



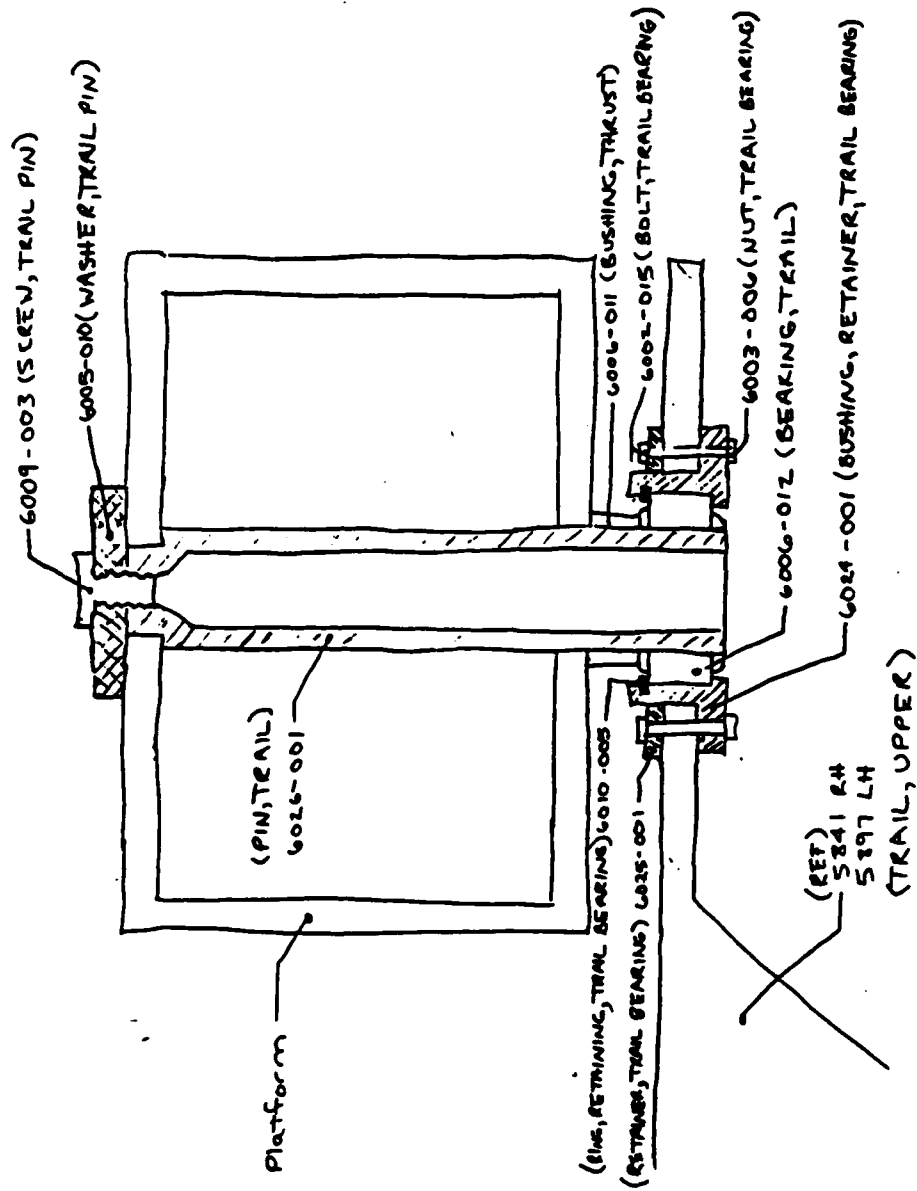
LTHD 43

15 JANUARY 1987

BA 36

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FMC

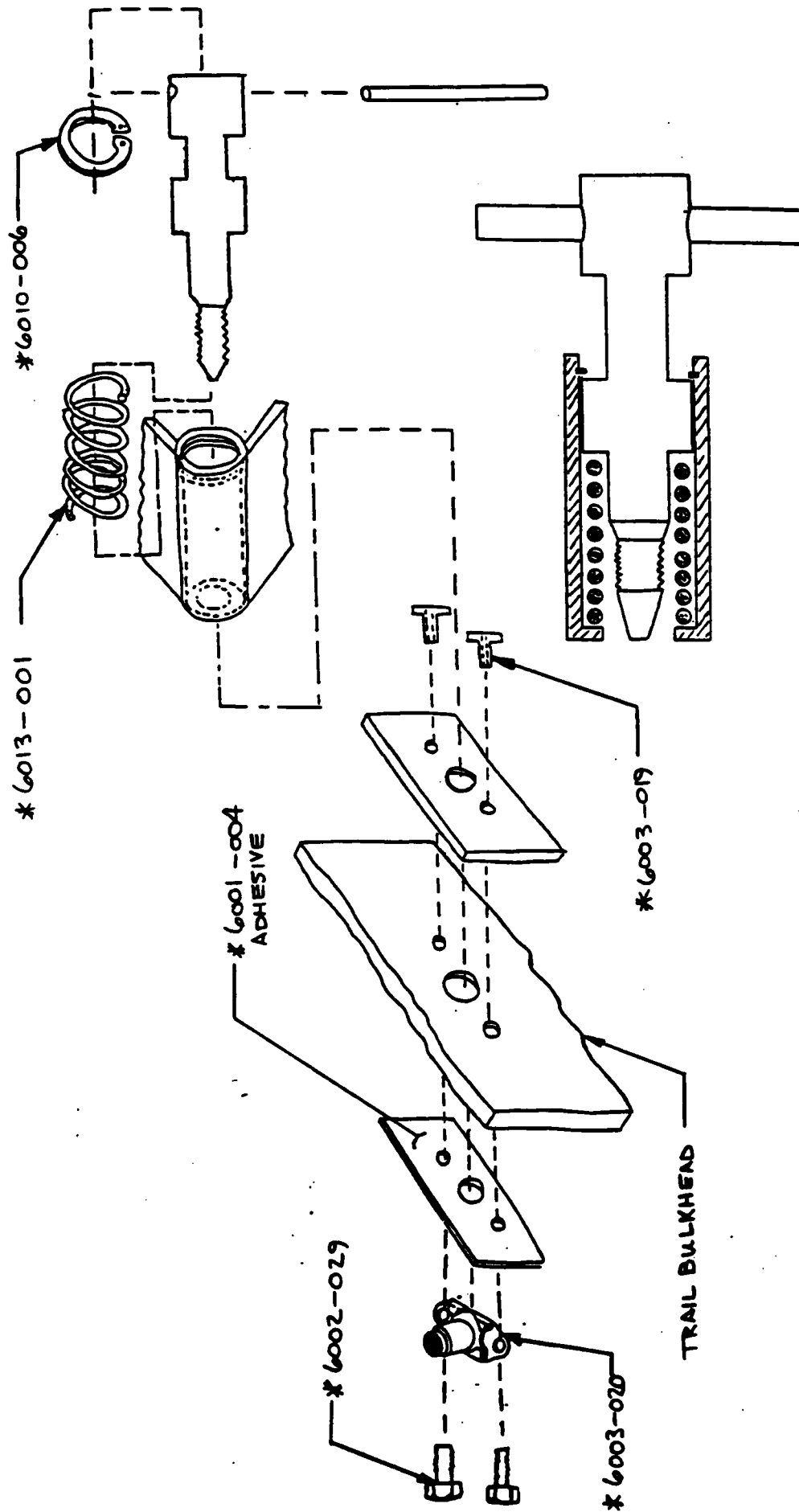


LTHD 44

15 JANUARY 1987

BA 37

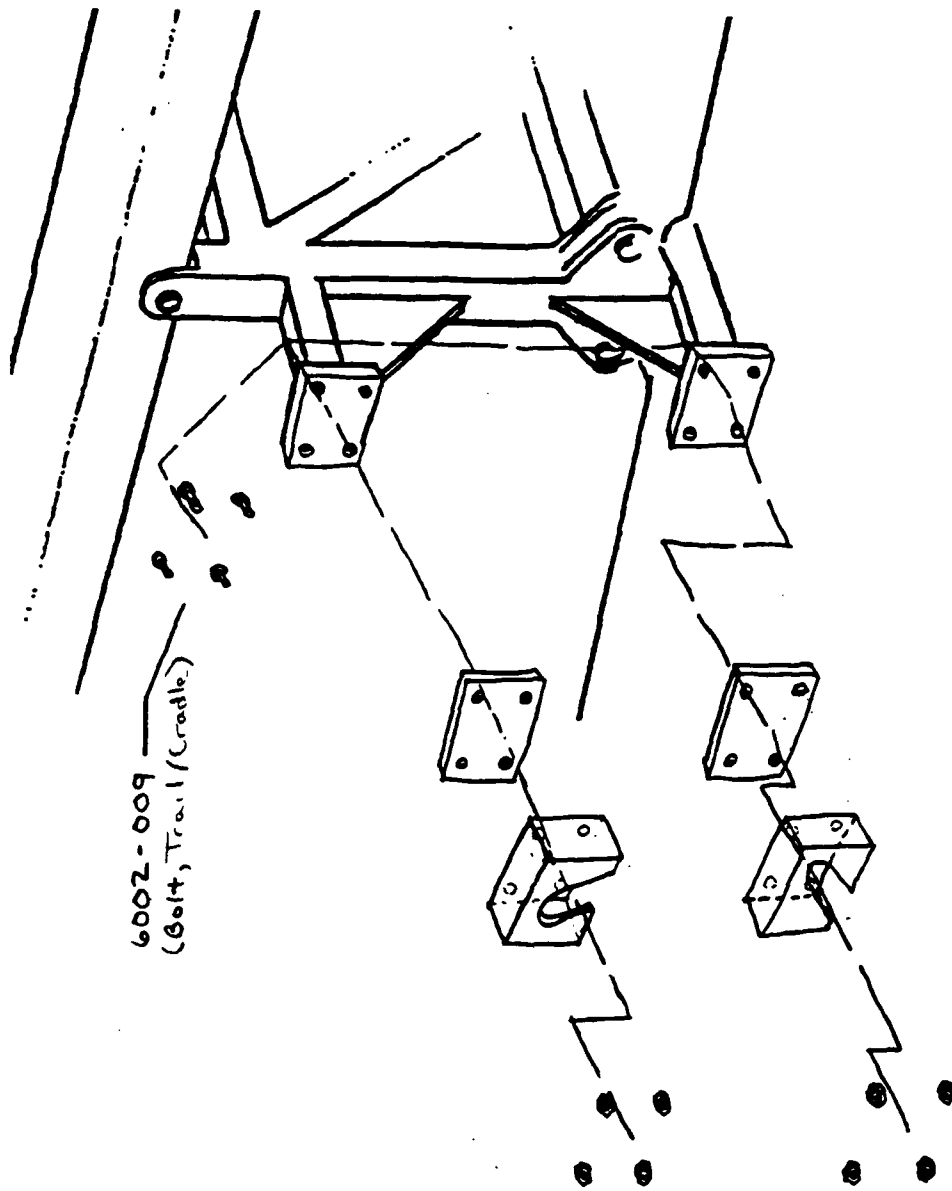
FMC



LTHD 45
15 JANUARY 1987
BA 38

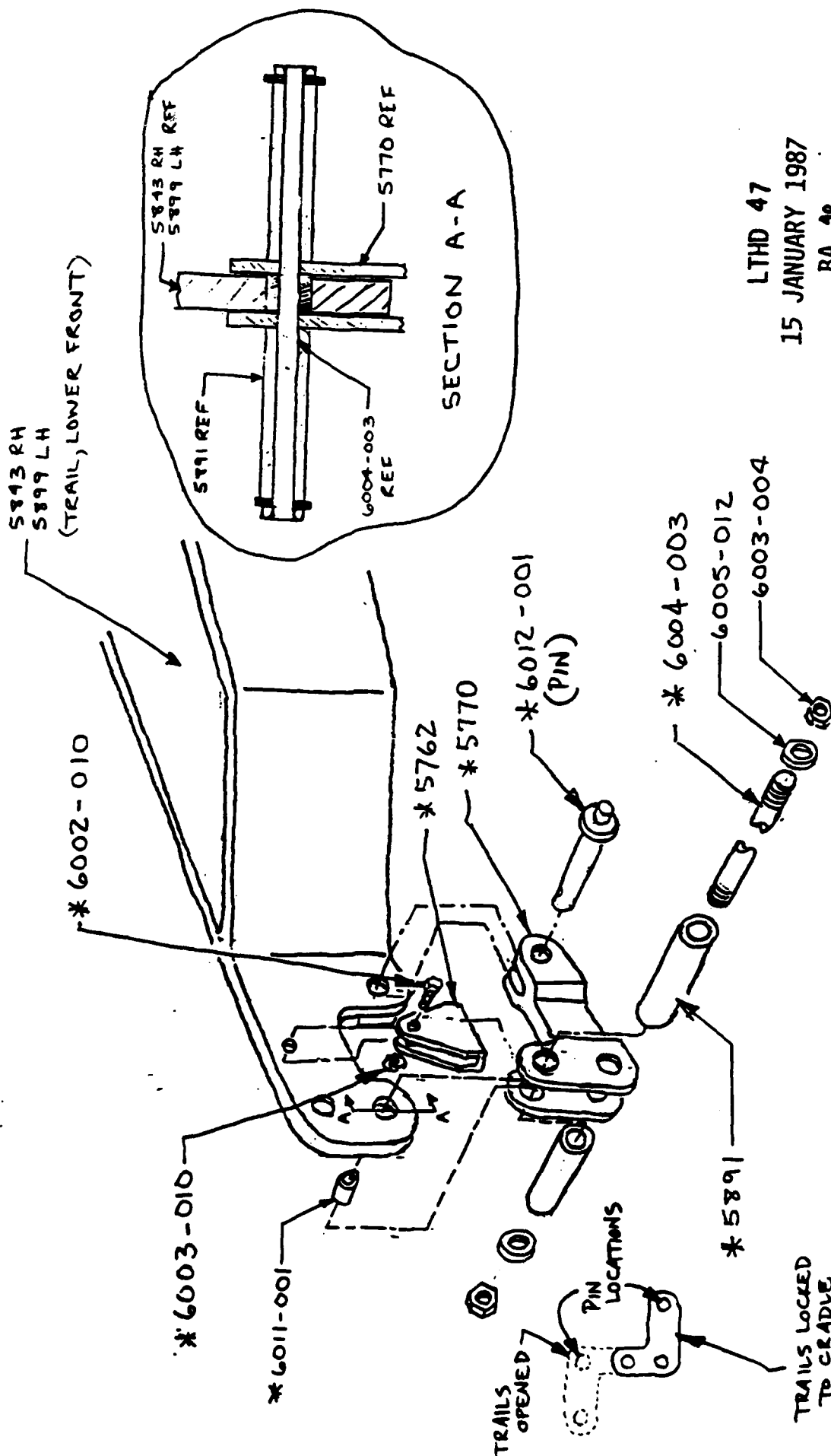
FMC

6002-009
(Bolt, Trail/Cradle)



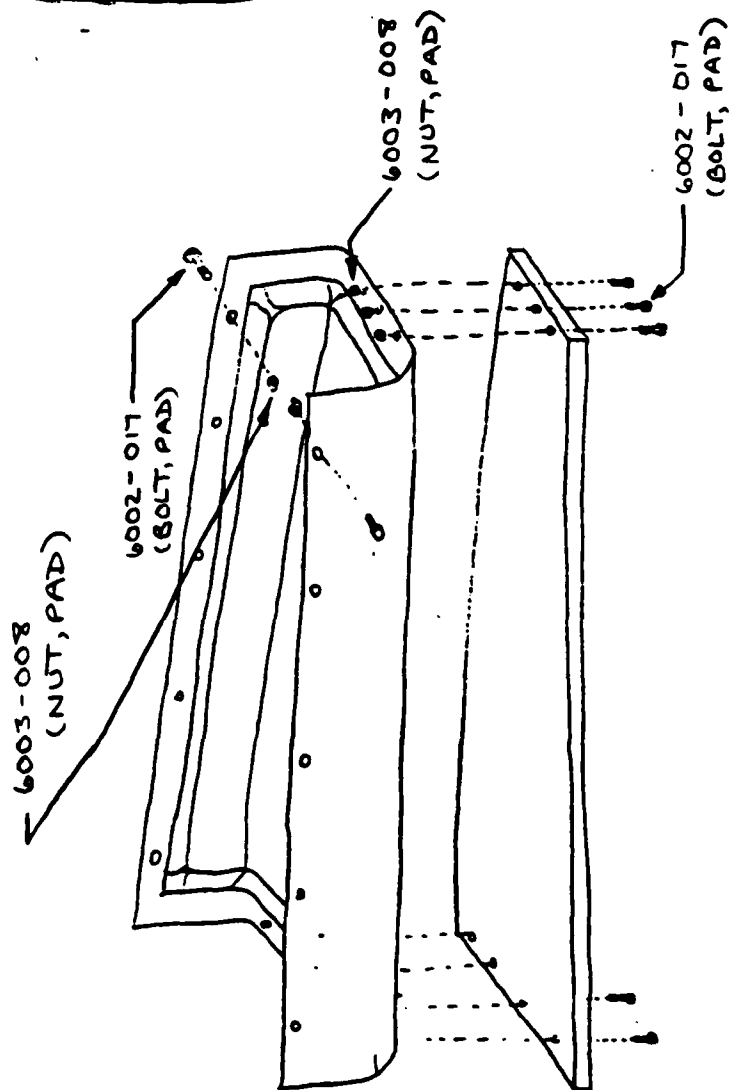
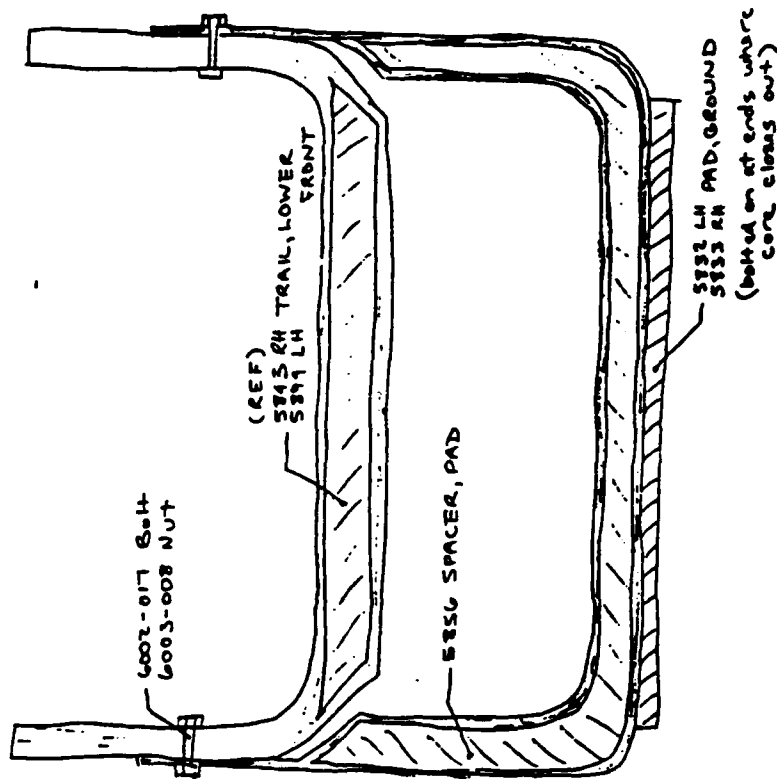
LTHD 46
15 JANUARY 1987
BA 39

FMC



LTHD 47
15 JANUARY 1987
BA 40

FMC

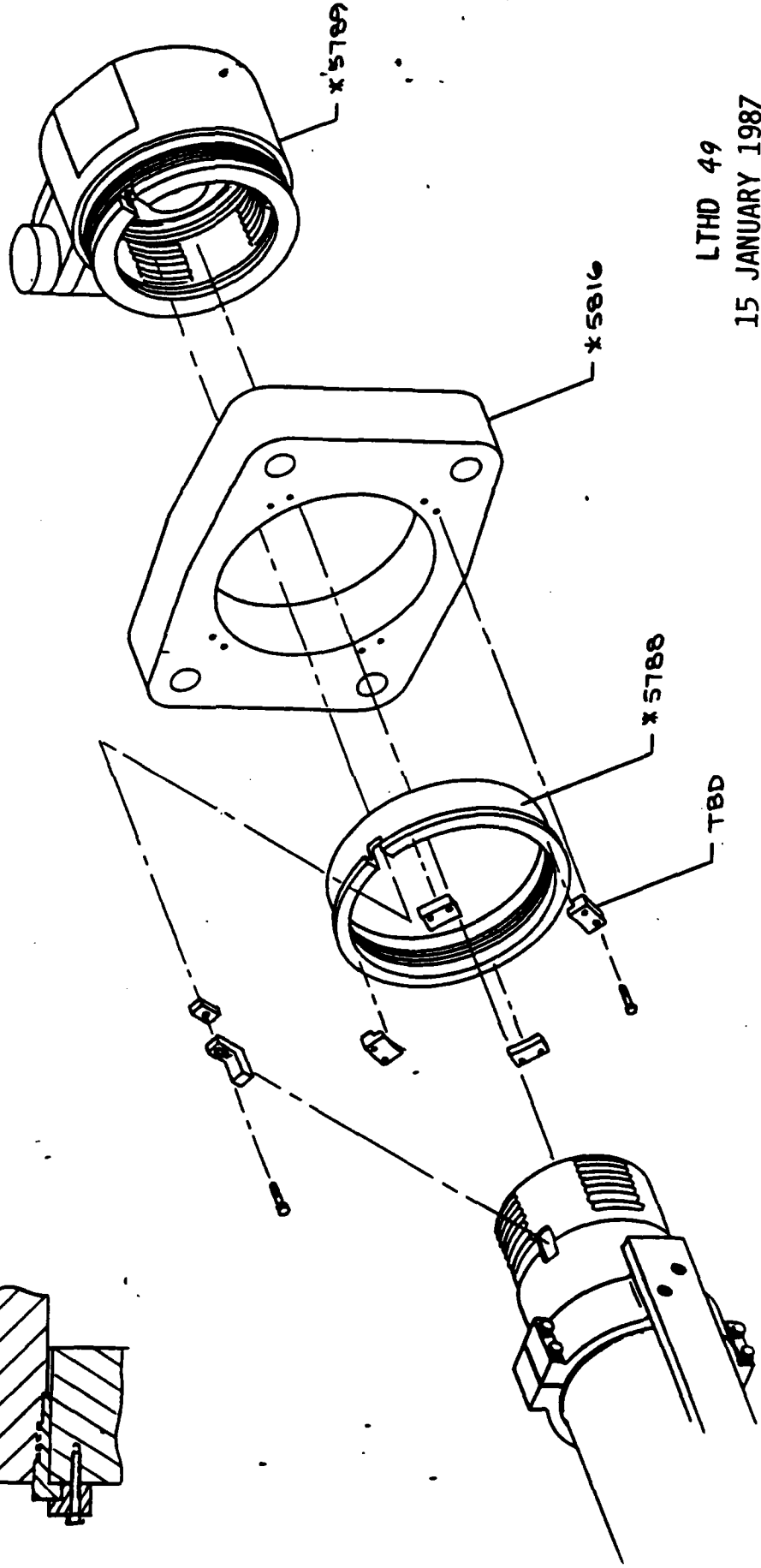
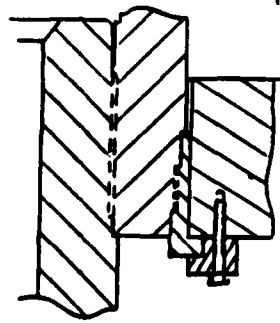


LTHD 48

15 JANUARY 1987

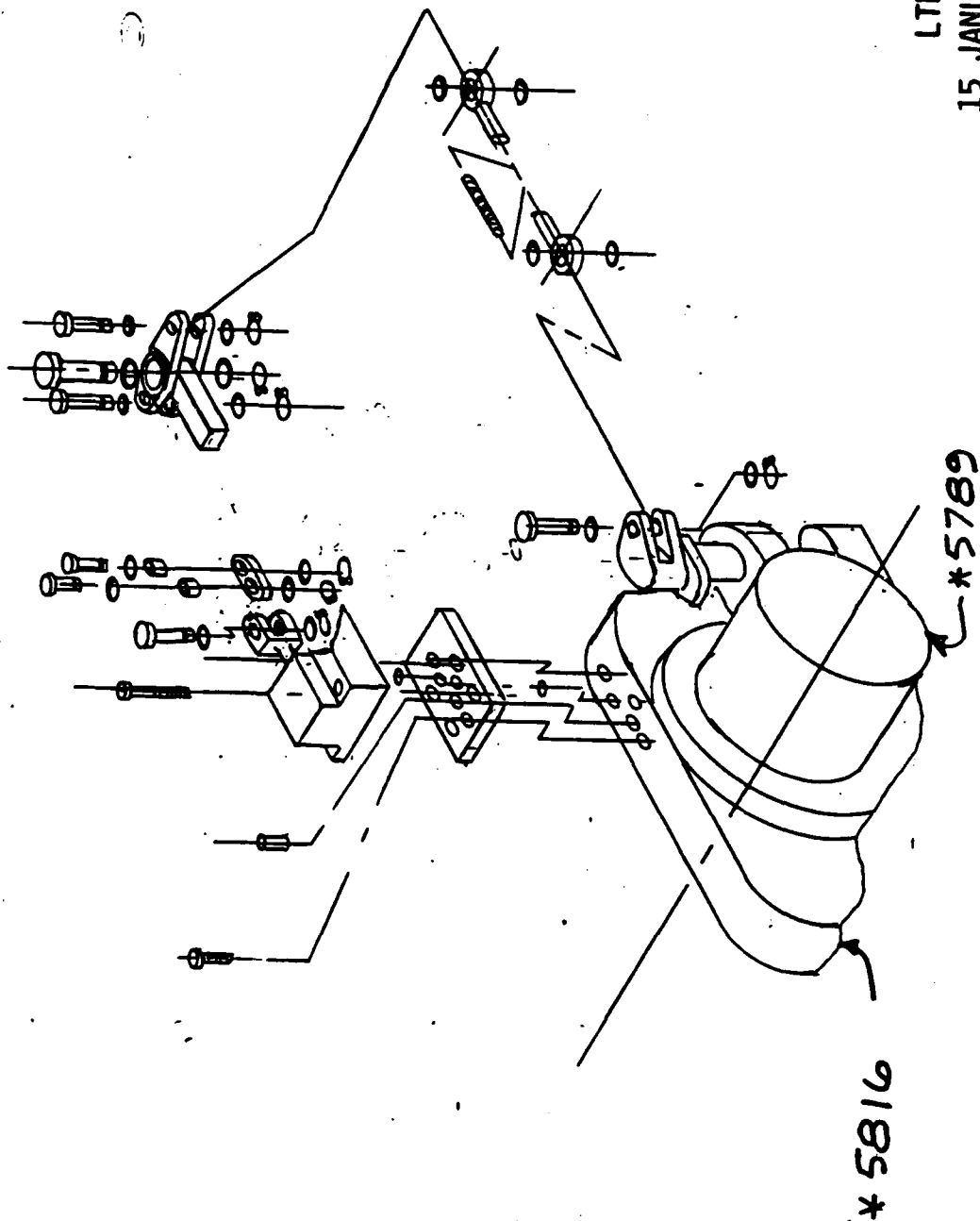
BA 41

FMC



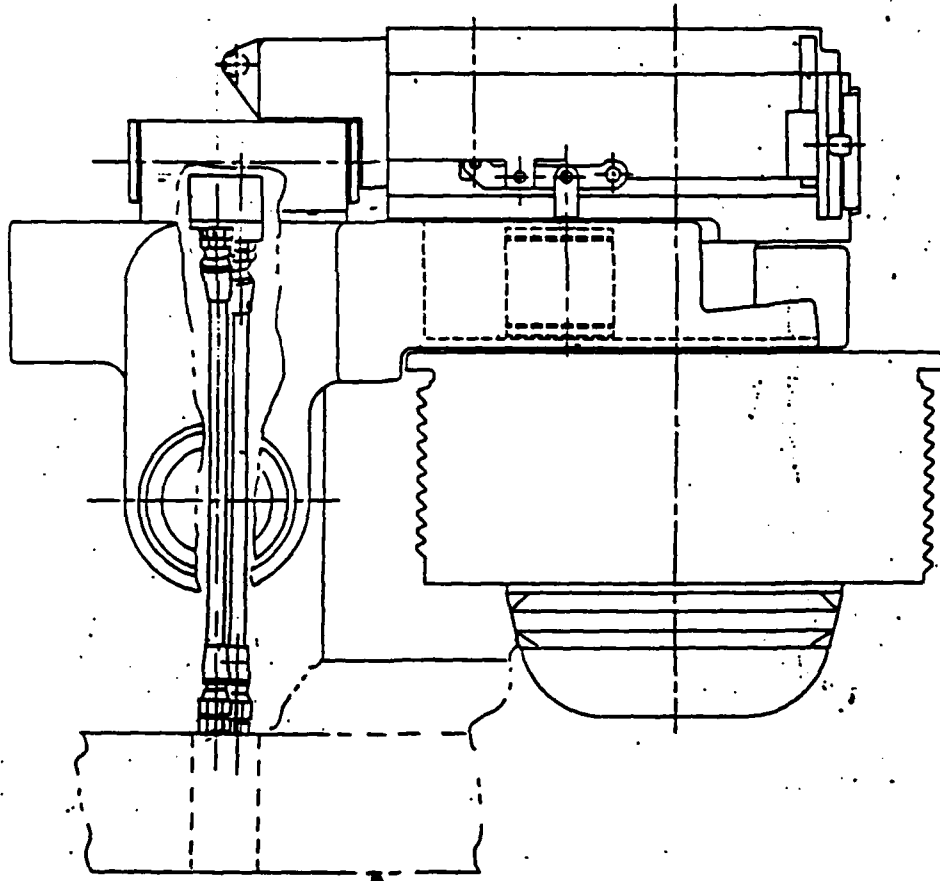
LTHD 49
15 JANUARY 1987
BA 42

FMC



LTHD 50
15 JANUARY 1987
BA 43

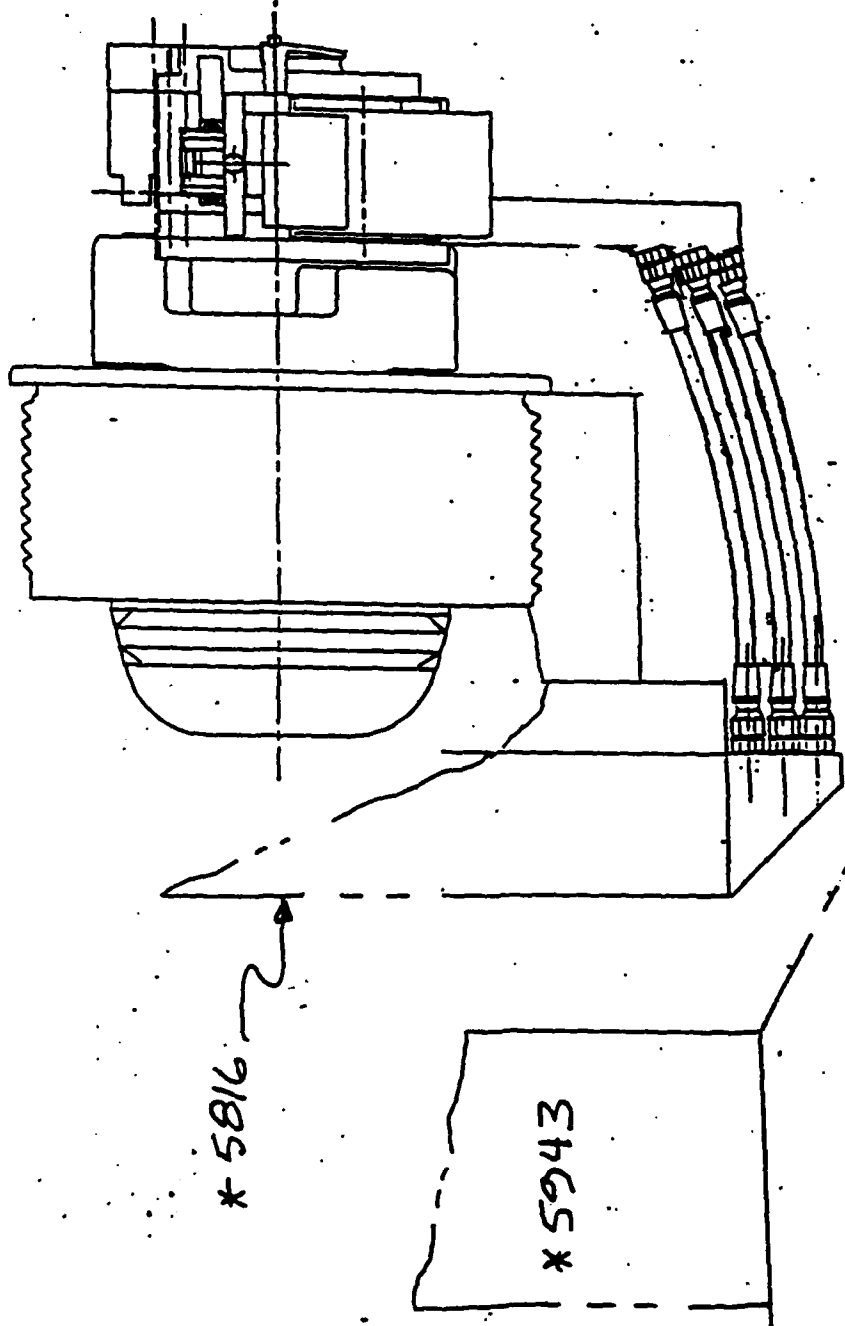
FMC



*5816

LTHD 5/
15 JANUARY 1987
BA 44

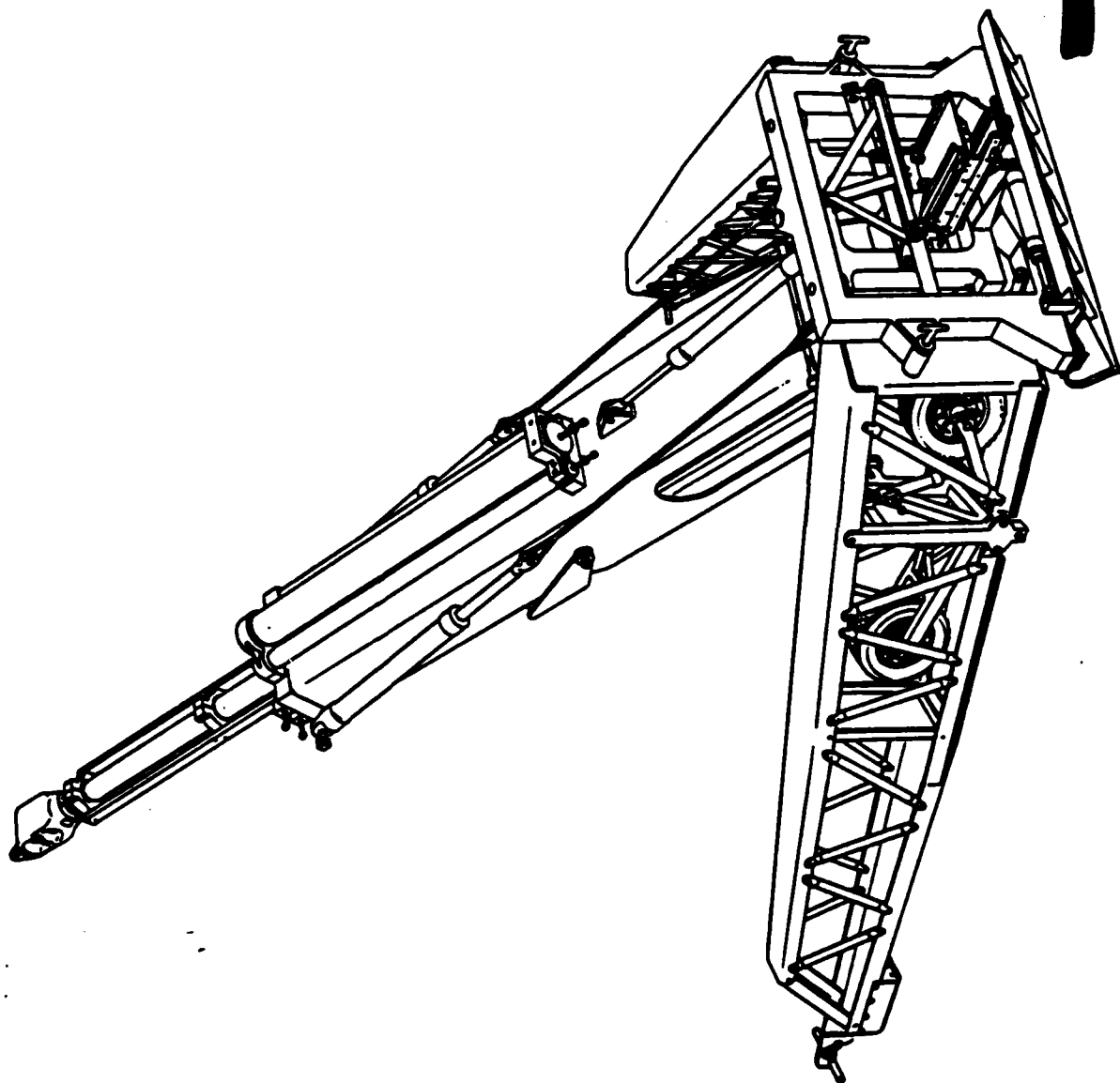
FMC



LTHD 52
15 JANUARY 1987
BA 4s



FMC

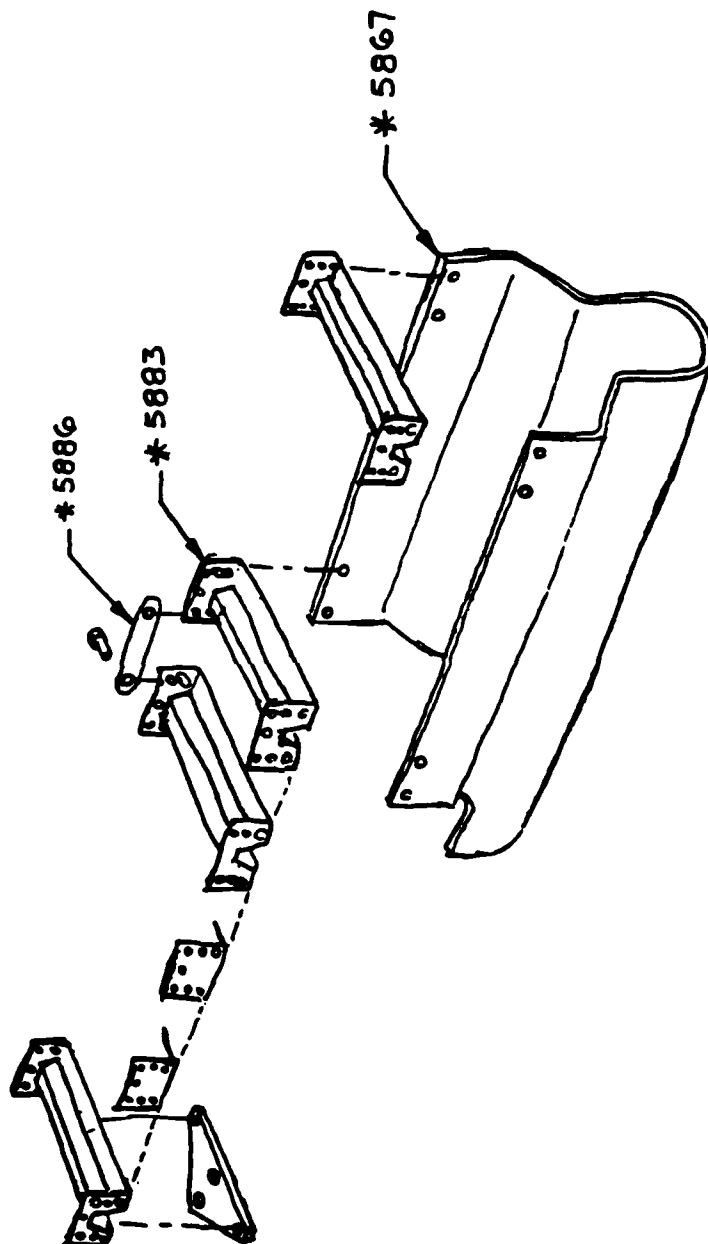


LTHD 53

15 JANUARY 1987.

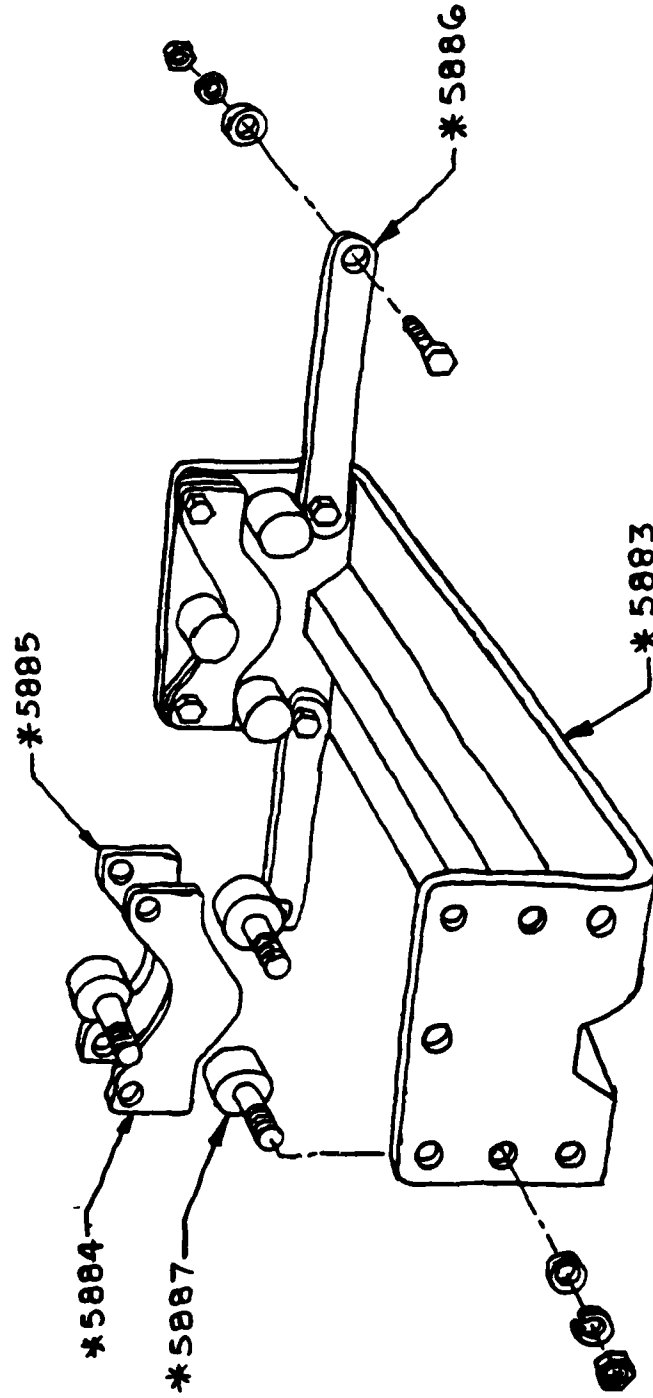
BA 46

FMC



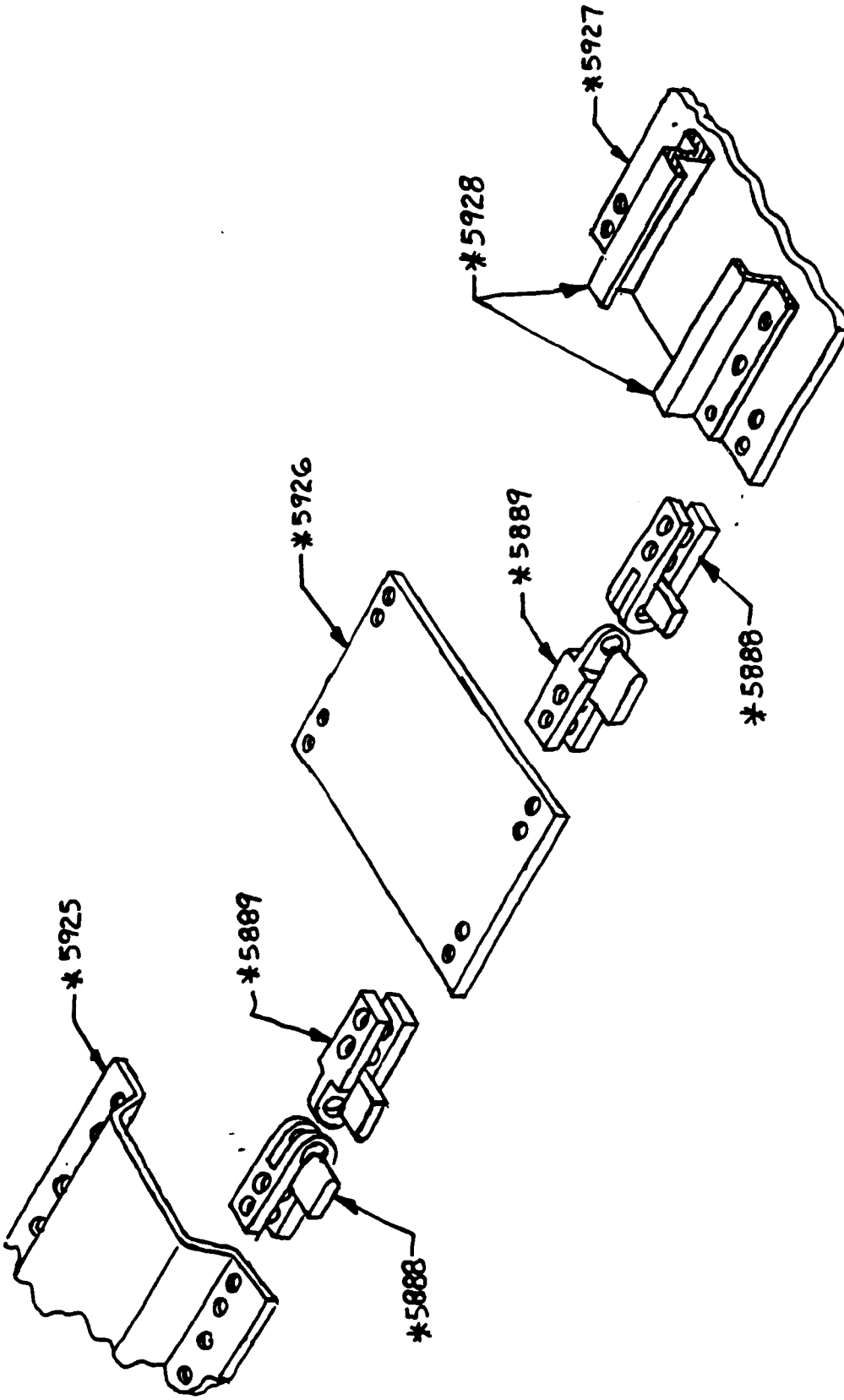
LTHD 54
15 JANUARY 1987
BA 47

FMC



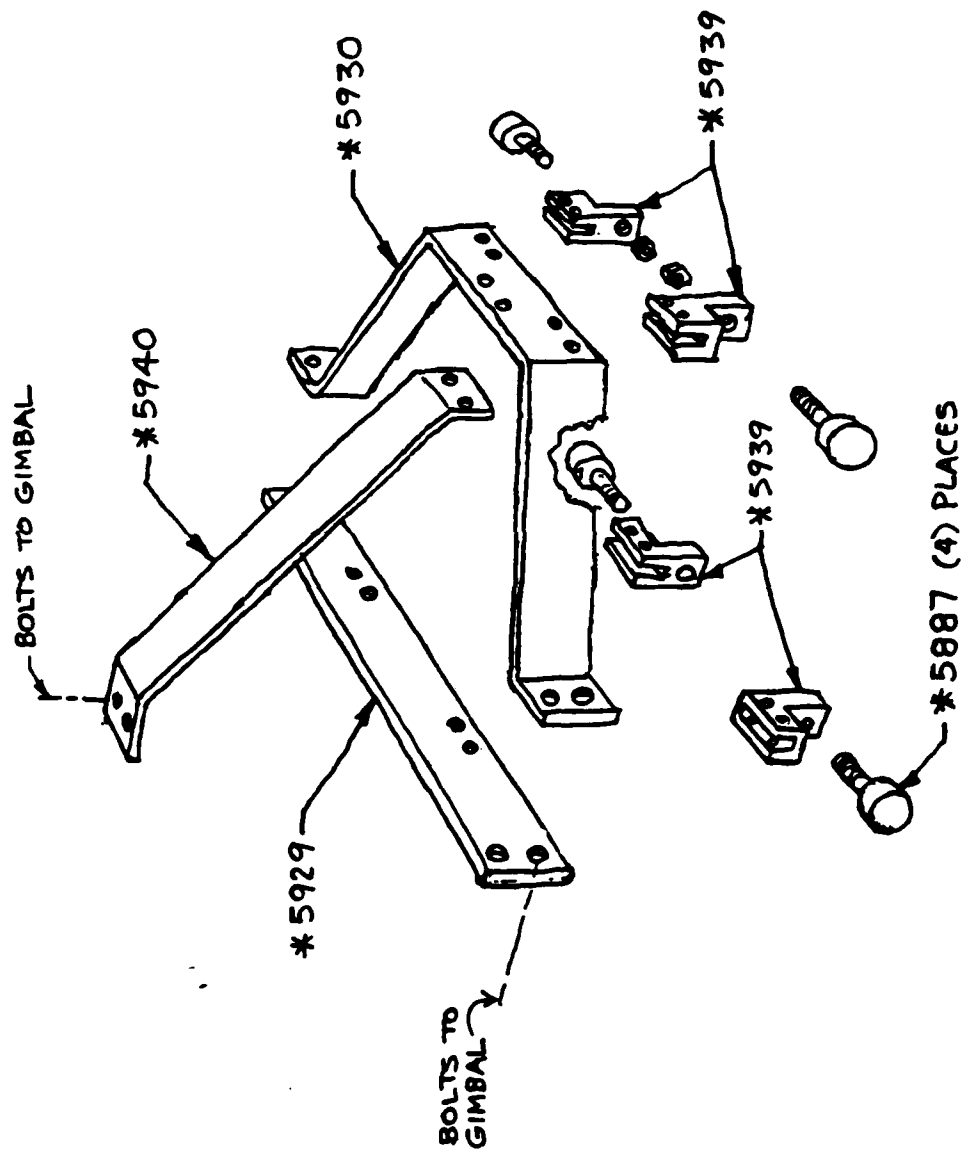
LTHD 55
15 JANUARY 1987
BA 48

FMC



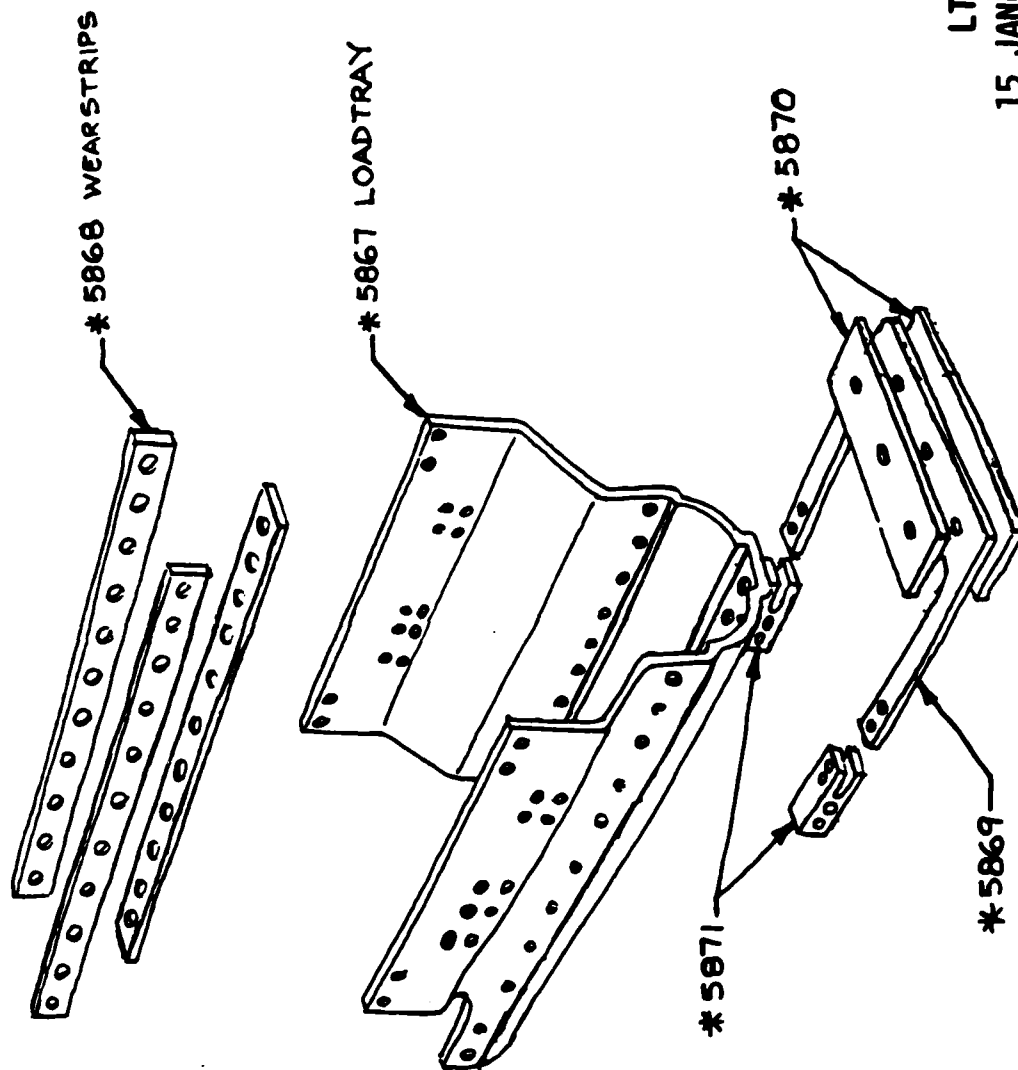
LTMD 56
15 JANUARY 1987
BA 4

FMC



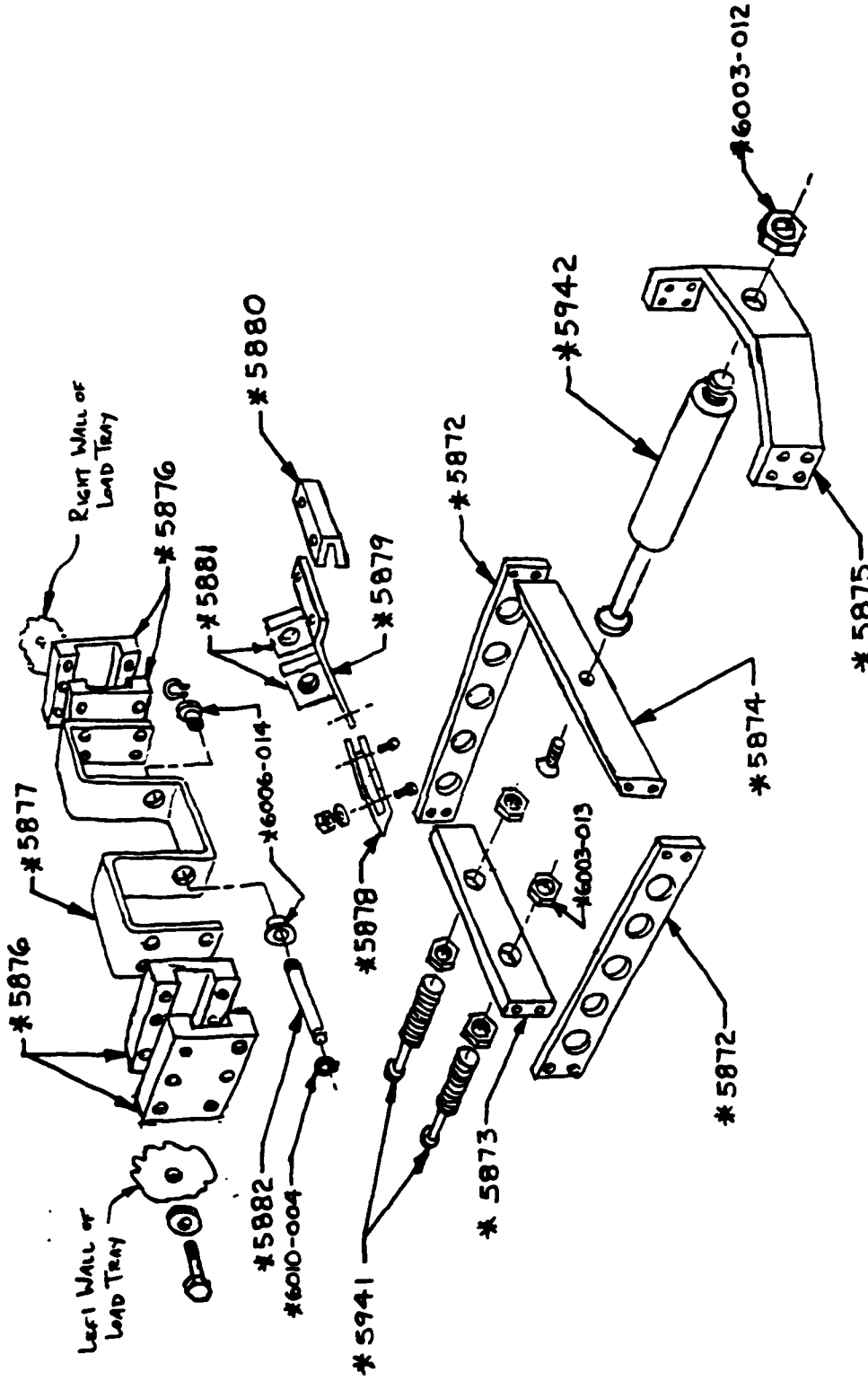
LTHD 57
15 JANUARY 1987
BA 50

FMC



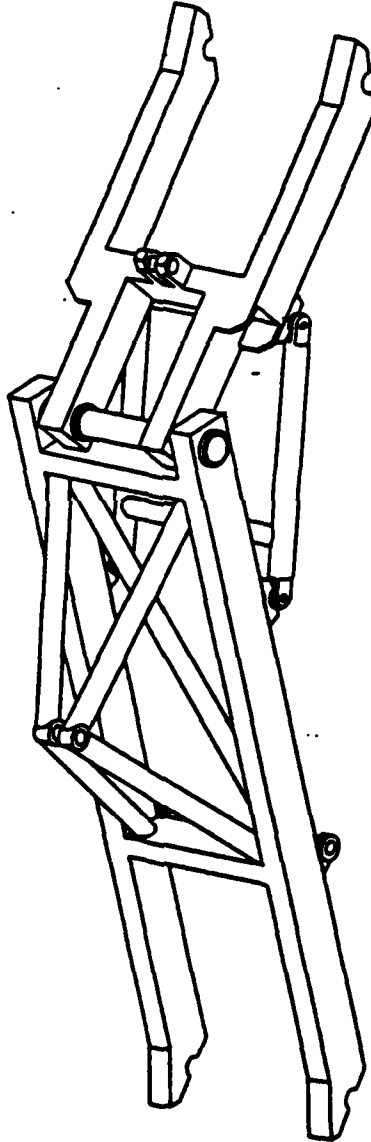
LTHD 58
15 JANUARY 1987
BA 51

FMC



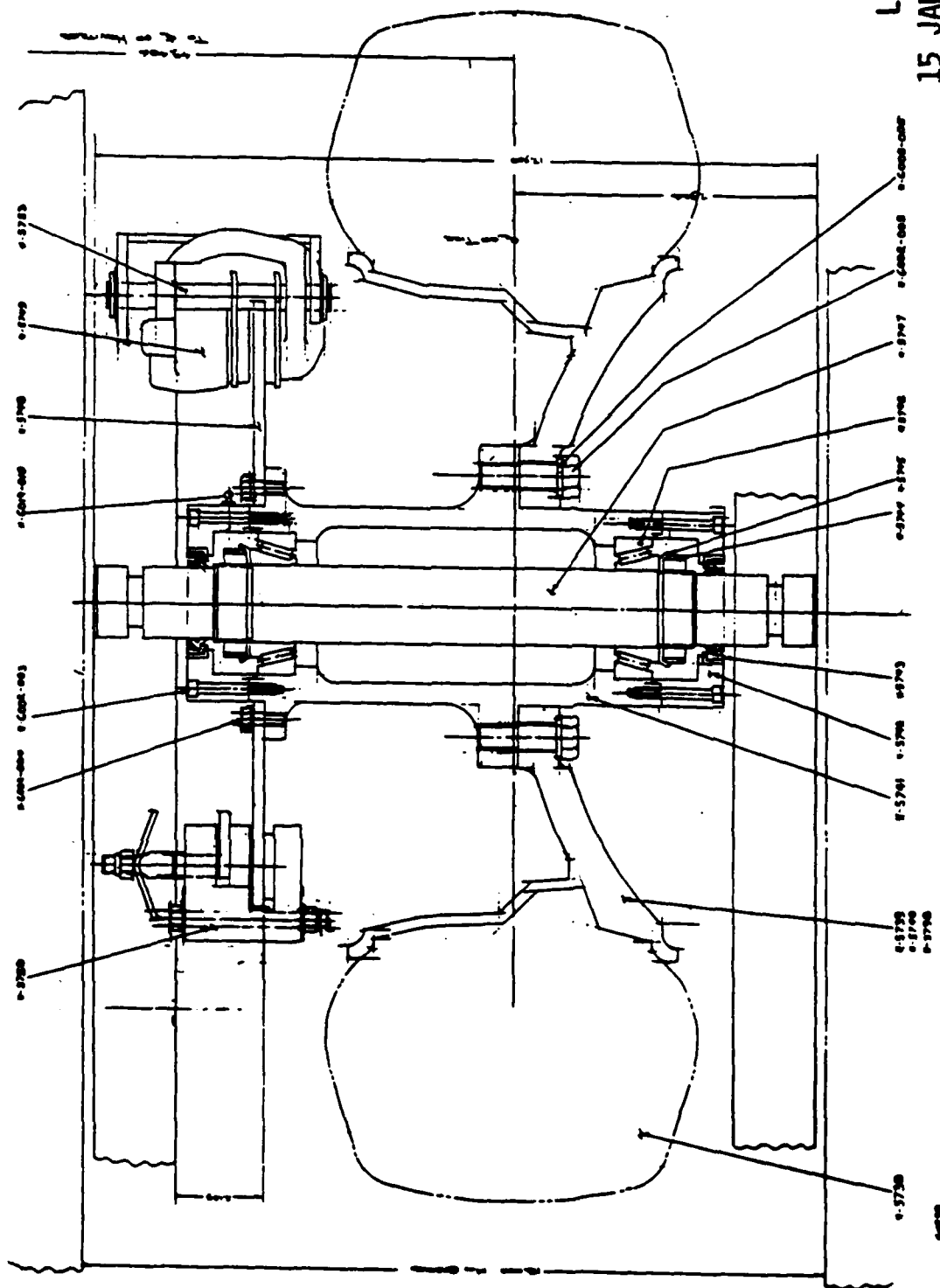
LTHD 59
15 JANUARY 1987
BA 52

FMC



LTHD 60
15 JANUARY 1987
BA 53

FMC

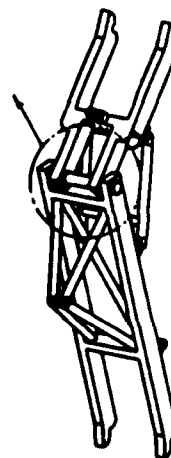


LTHD 61
15 JANUARY 1987
BA 54

[illegible]

LTHD 62
15 JANUARY 1987
BA 55

62



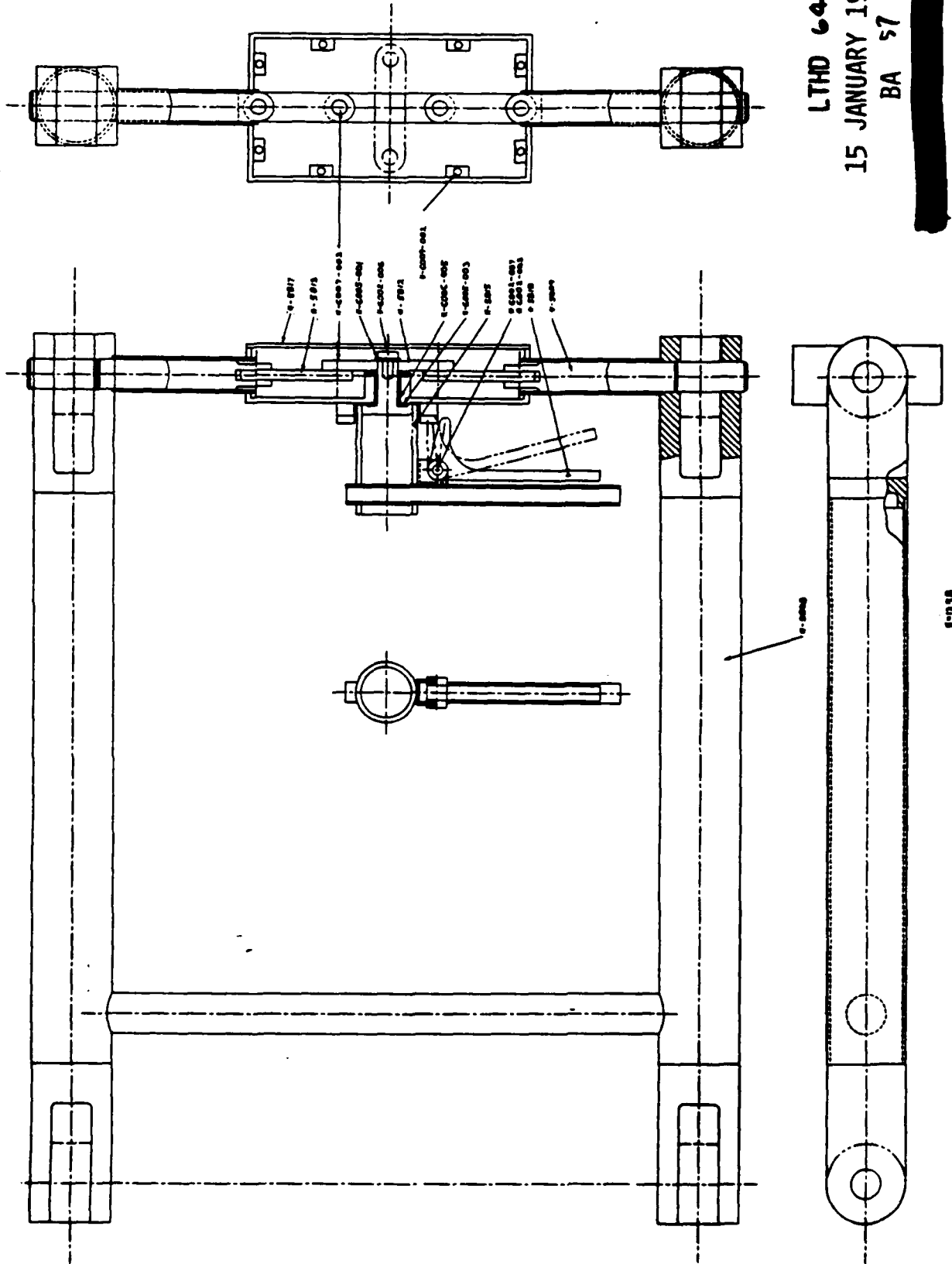
Technical drawing of a mechanical assembly, likely a crane or lifting device. The drawing includes a side view on the left and a top view on the right. The side view shows a vertical frame with a horizontal beam and a pulley system. The top view shows a complex arrangement of beams, pulleys, and cables. Various parts are labeled with alphanumeric codes.

Labels in the side view (left):

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100

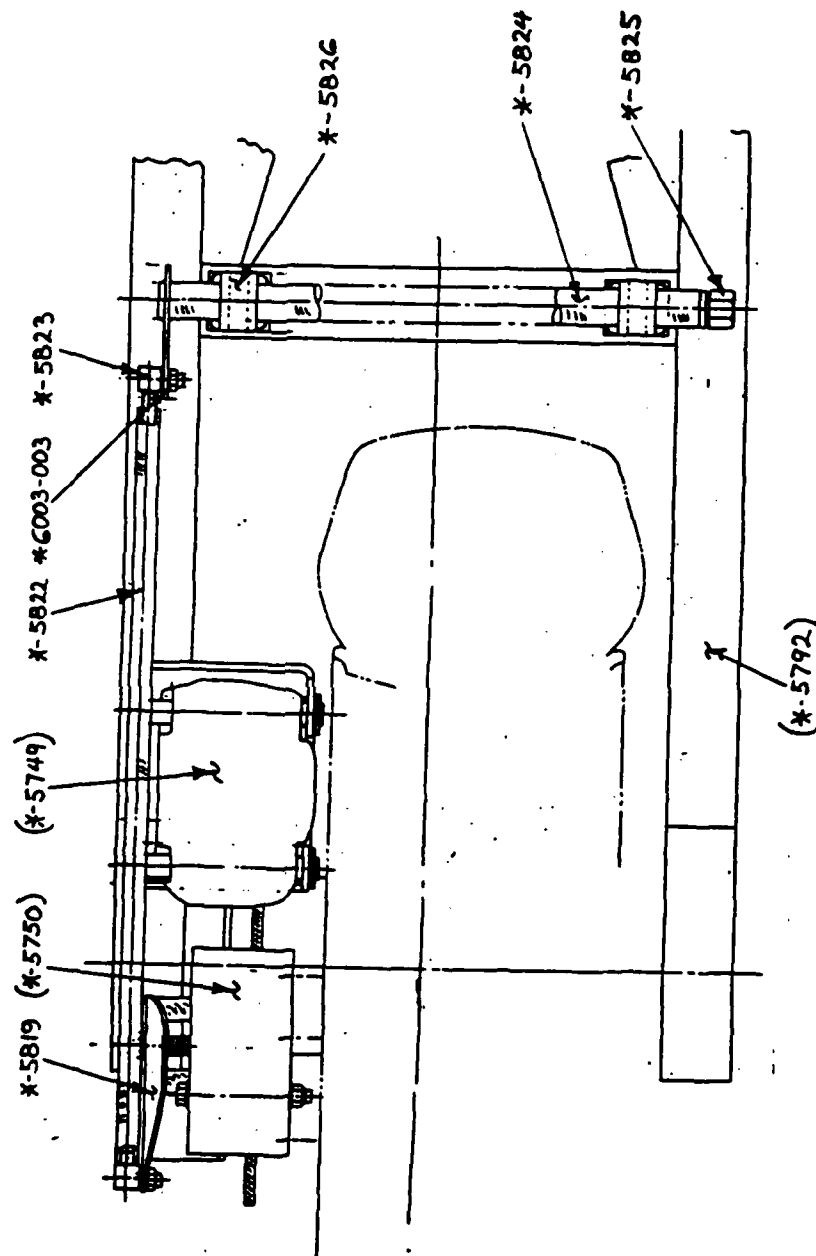
FMC



LTHD 64
15 JANUARY 1987
BA 57

FMC

**PARK BRAKE ASSEMBLY
WALKING BEAM (SHT. 1)**

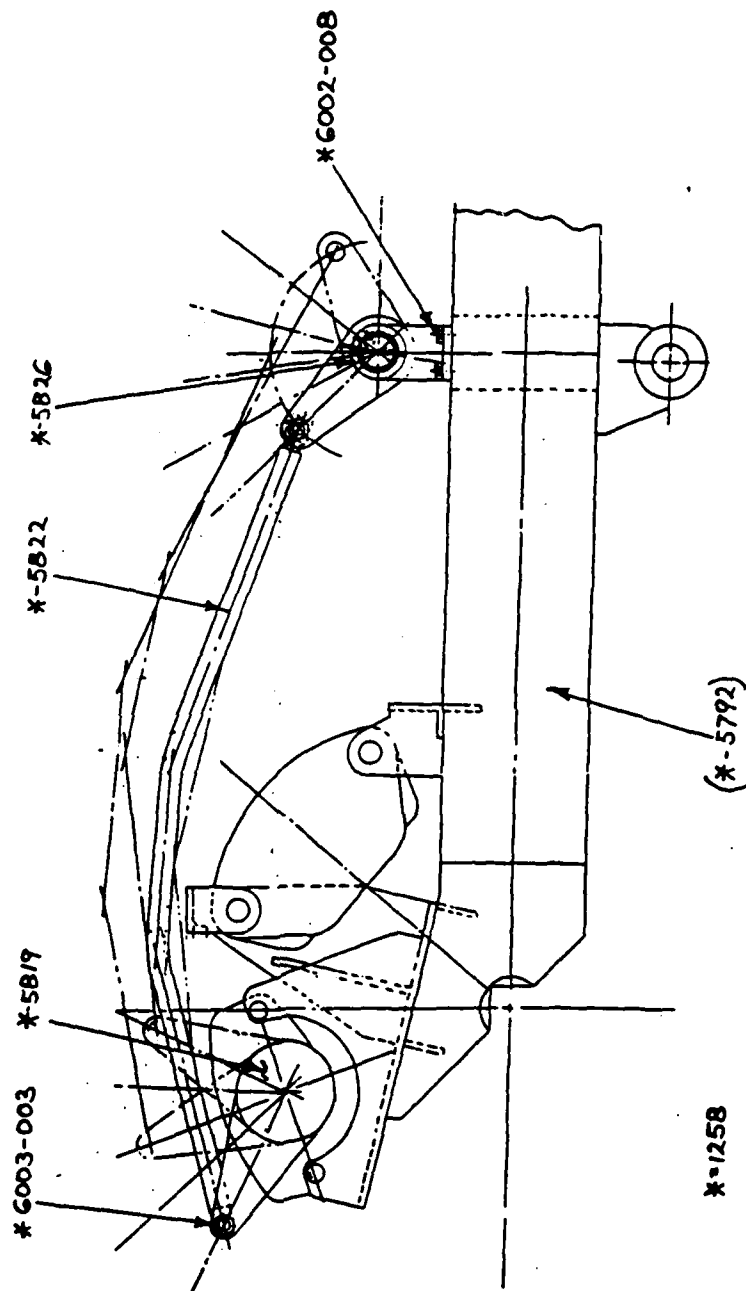


*-1258

LTMD 65
15 JANUARY 1987
BA 58

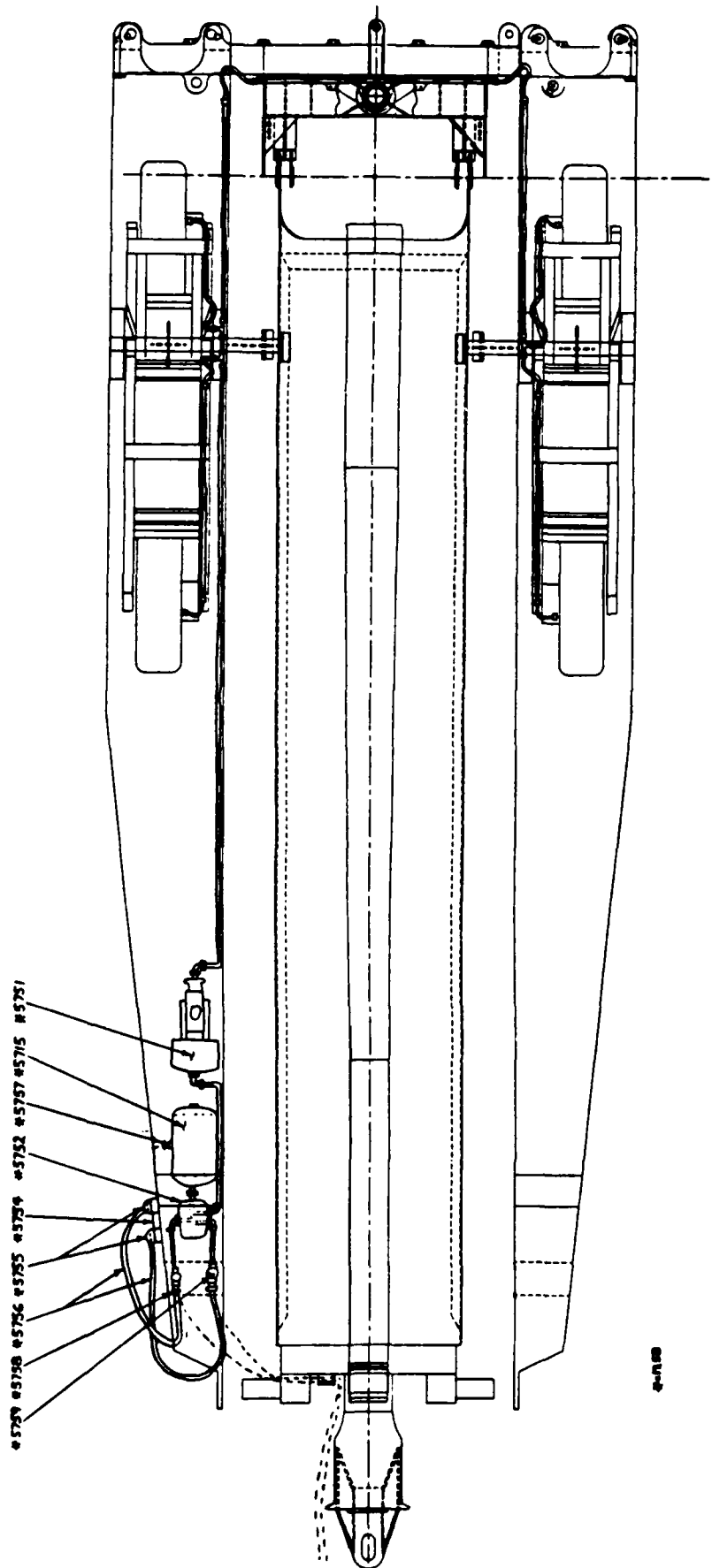
FMC

**PARK BRAKE ASSEMBLY
WALKING BEAM (SHT. 2)**



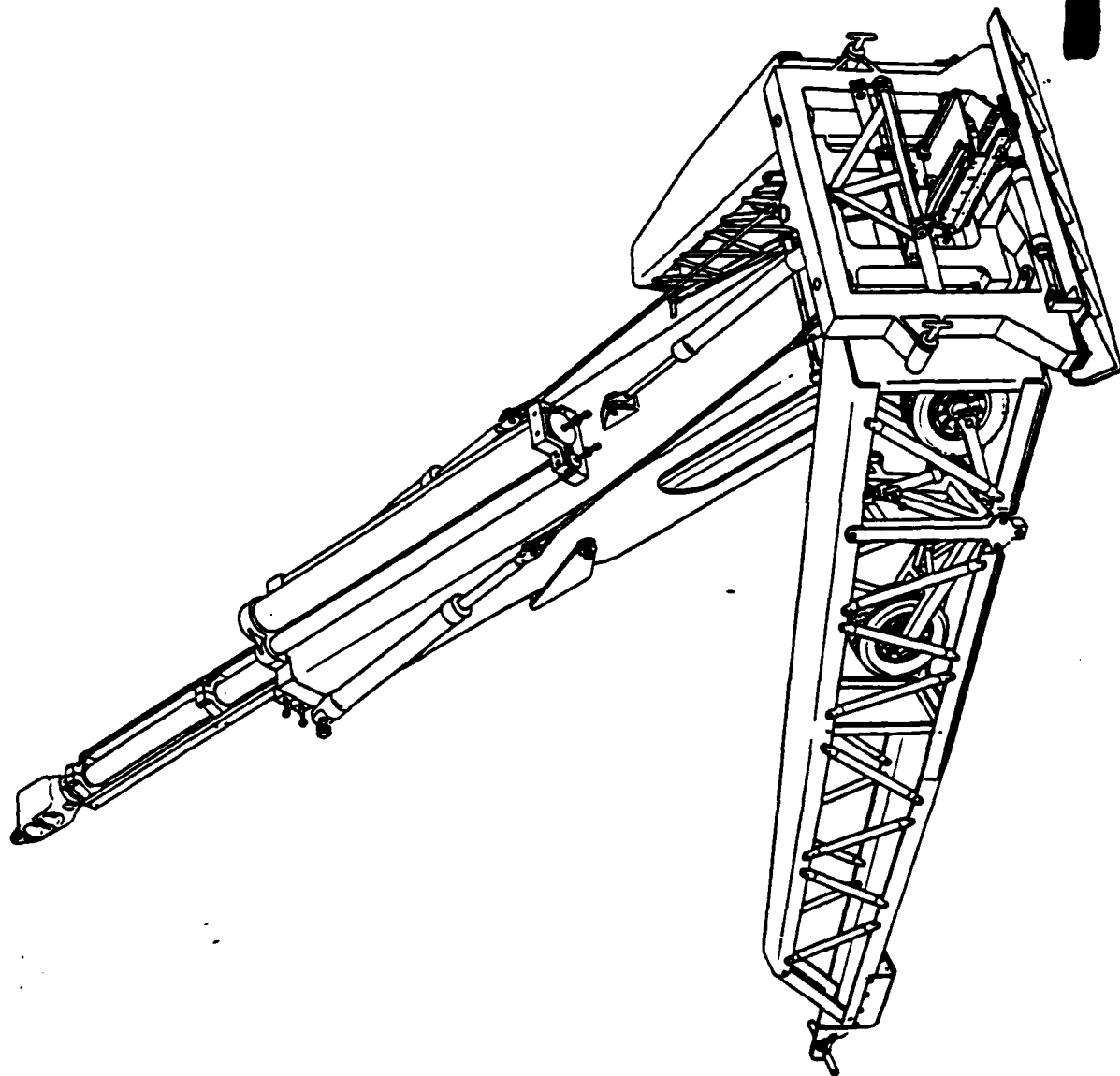
LTHD 66
15 JANUARY 1987
BA 59

FMC



LTHD 67
15 JANUARY 1987
BA 60

FMC



LTHD 68
15 JANUARY 1987
BA 61

FMC

TRADE MADE AT FIRE CONTROL

SEQUENCE OF EVENTS AND RATIONALE

**EMPLOY M198 FIRE CONTROL AND COMPLY WITH HUMAN FACTORS REQUIREMENTS
REQUIRED BY STATEMENT OF WORK**

COMPLICATIONS

**M138 DIRECT FIRE SCOPE MUST BE RAISED 4.5" TO SEE OVER PLATFORM
(DROPPING PLATFORM TOP 4.5" WOULD RAISE WEIGHT BY OVER 50 LBM)
RAISING FC TRUNNION 4.5" NECESSITATES ADDITION OF 50 LBM PLATFORM
FOR BOTH GUNNER AND ASSISTANT GUNNER**

M138 DIRECT FIRE SCOPE EYE PIECE IS 90° TUBE Q

**MOVES FC 12" BEYOND LOAD TRAY ENTRANCE FOR 400 MIL TRAV L
ACCESS TO LOAD TRAY REQUIRES REACHING UNDER FC TRUNNION SHAFT
INCREASES OVERALL LENGTH 12"**

**LTHD 69
15 JANUARY 1987
BA 62**

FMC

TRADE MADE AT FIRE CONTROL (CONTINUED)

SITUATION ANALYSIS

IF A DIRECT FIRE SCOPE WITH A 4.5" PERISCOPE AND REAR EYE PIECE WERE USED

ACCESS TO LOAD TRAY WOULD BE SATISFACTORY

HUMAN FACTORS FOR ASSISTANT GUNNER WOULD BE SATISFACTORY

50 LBM WEIGHT PENALTY WOULD BE AVOIDED

IF AN M138 DIRECT FIRE SCOPE WERE USED

DIRECT FIRE BELOW 7° WOULD NOT BE POSSIBLE

TRAY L BEYOND 175 MILS WOULD EXCEED HF LIMITS FOR AG

DECISION

TRADE

50 LBM WEIGHT/PENALTY

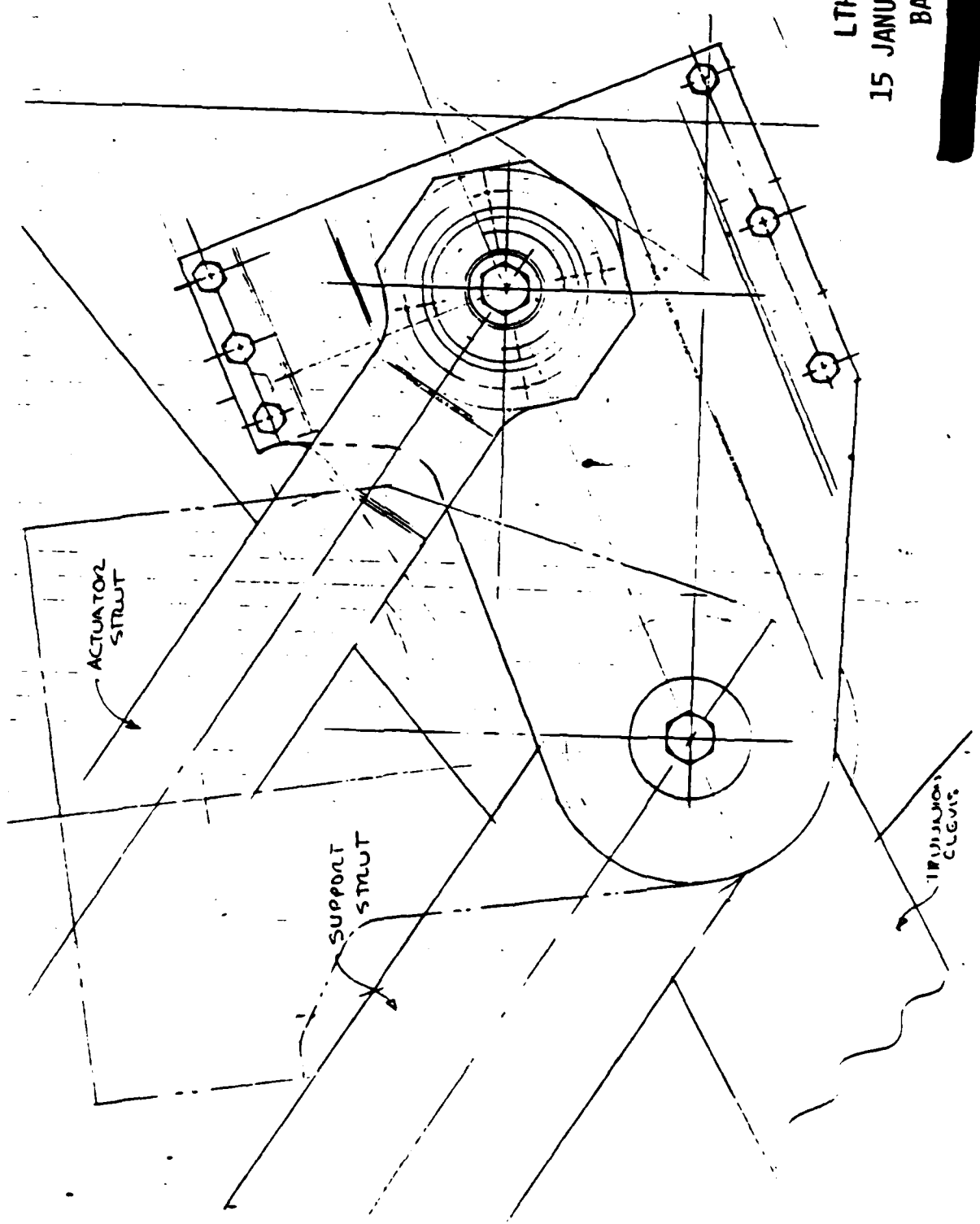
POOR ACCESS TO LOAD TRAY

INCREASED OVERALL LENGTH

NON M198 DIRECT FIRE SCOPE
OR
M198 DF SCOPE W/AZ & QE LIMITS

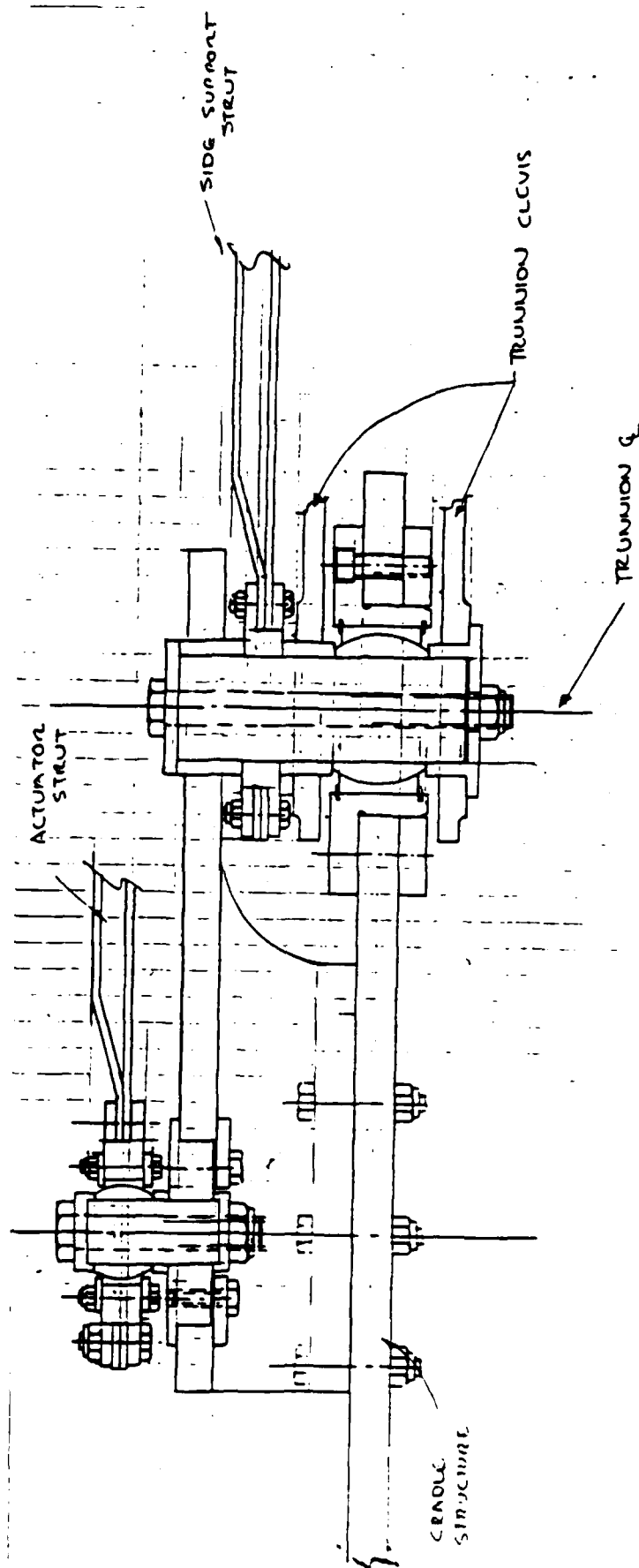
LTHD 70
15 JANUARY 1987
BA 63

FMC



LTHD 71
15 JANUARY 1987
BA 64

FMC



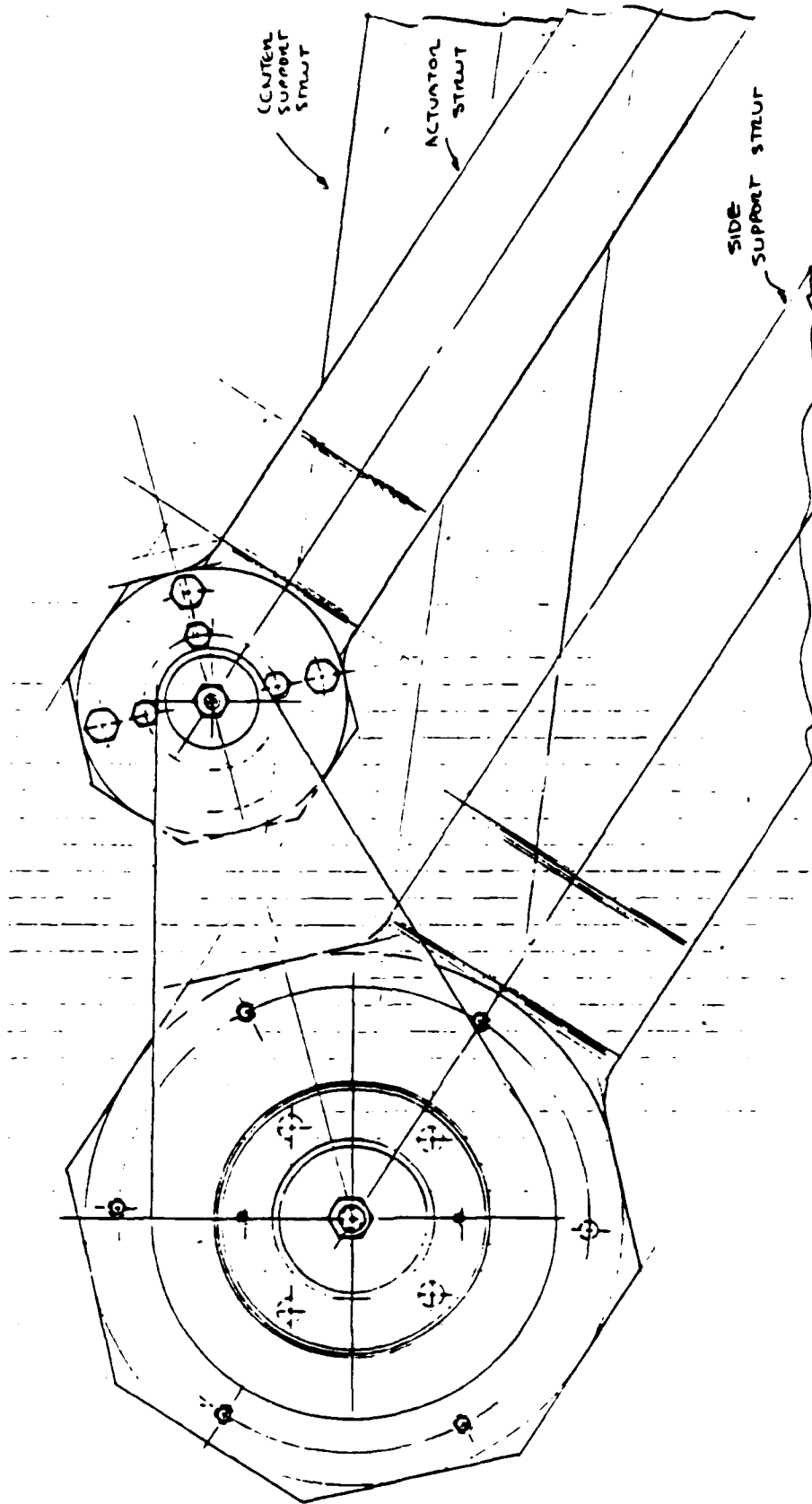
LTHD 72

15 JANUARY 1987

BA 65

72

FMC



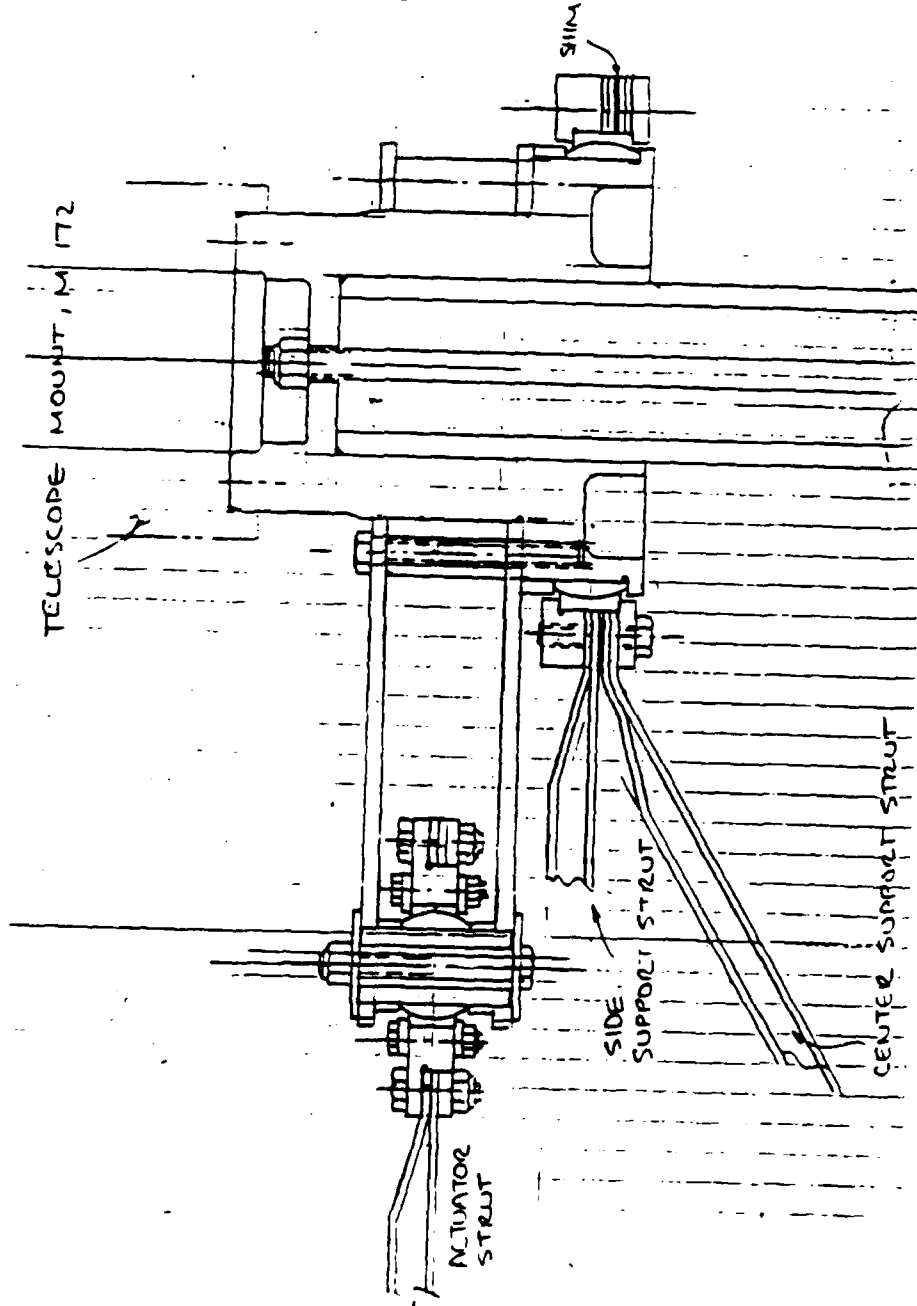
LTHD 73

15 JANUARY 1987

BA 4

73
64

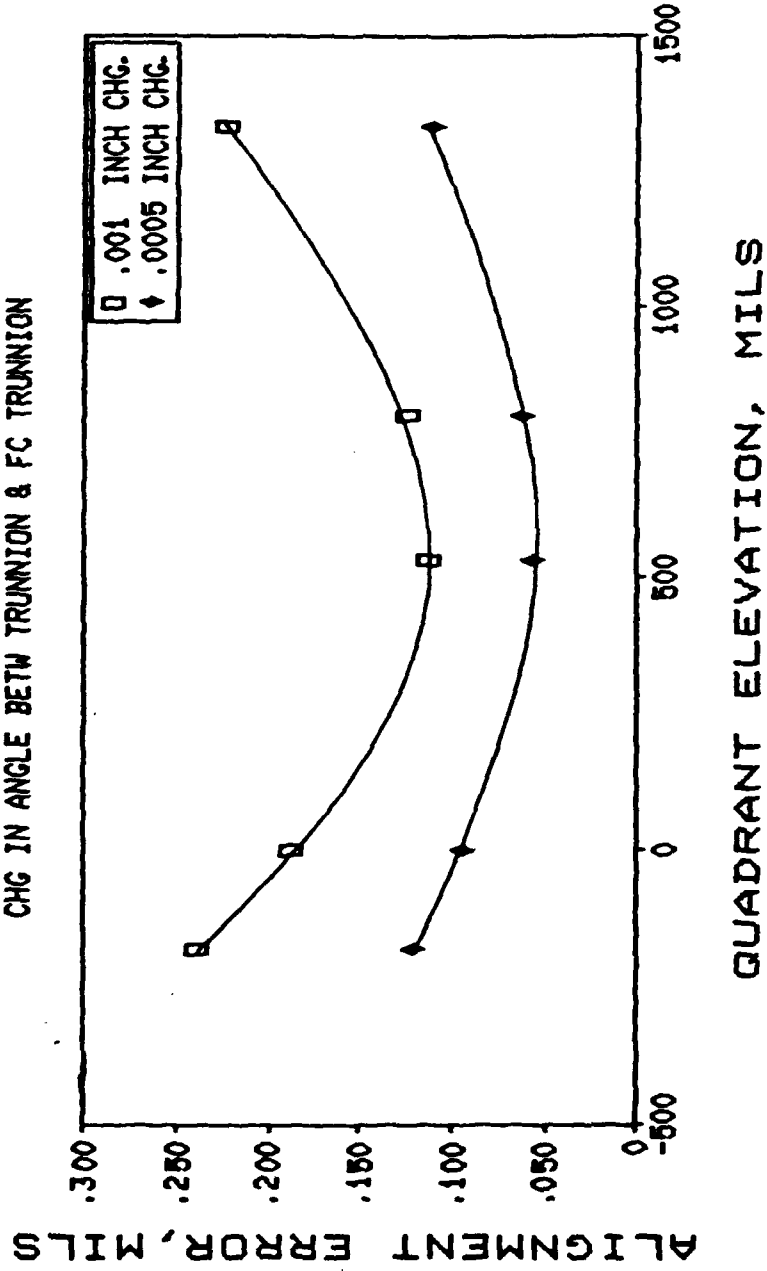
FMC



LTHD 74
15 JANUARY 1987
BA 67

FMC

FIRE CONTROL ALIGNMENT ERROR VS Q.E.
CHG IN ANGLE BETW TRUNNION & FC TRUNNION



LTHD 75
15 JANUARY 1987
BA 68

STRUCTURAL ANALYSIS

FMC

OUTLINE

- 0 GENERAL
- 0 ENVIRONMENTS/CONFIGURATIONS
- 0 MATERIALS - METALS
- 0 MATERIALS - COMPOSITE
- 0 SYSTEM - FEA (FINITE ELEMENT ANALYSIS)
- 0 CRADLE - FEA
- 0 TRAIL - FEA
- 0 PLATFORM/GIMBAL/SPADE - FEA
- 0 LEADING/LAGGING BEAM (WHEEL ASSEMBLY) - FEA
- 0 MUZZLE BRAKE
- 0 MISCELLANEOUS PARTS
- 0 SUMMARY FEA ANALYSIS
- 0 SUMMARY OTHER ANALYSIS
- 0 CONCLUSIONS
- 0 ANALYSIS PLANS

LTHD 76
15 JANUARY 1987
LL

STRUCTURAL ANALYSIS

FMC

GENERAL

0 GOAL:

- ASSURE THAT LTHD COMPONENTS HAVE ADEQUATE STRENGTH/STIFFNESS AND MINIMUM WEIGHT FOR THE ANTICIPATED ENVIRONMENTS

0 ANALYSIS TECHNIQUE:

HAND CALCULATIONS

- DETERMINE FREE BODY DIAGRAMS FOR "STATIC" LOADS
- SIZE INTERCONNECTION COMPONENTS (PINS, BEARINGS, FASTENERS)
- DETERMINE STRESS IN MINOR COMPONENTS

FINITE ELEMENT ANALYSIS (FEA)

- DETERMINE GROSS STRESSES AND DEFLECTION IN MAJOR COMPONENTS
- DETERMINE MODE/FREQUENCIES
- DETERMINE DYNAMIC LOADINGS

0 MAJOR COMPONENTS: CRADLE, PLATFORM, GIMBAL, SPADE, TRAIL, LEADING/LAGGING BEAM

0 DESIGN CRITERIA (PHILOSOPHY)

- PROOF FIRING LOADS (DYNAMIC OR STATIC)
- STATIC TRANSPORTATION LOADS
- NO FATIGUE CONSIDERATIONS
- FACTOR OF SAFETY (F.S.): MINIMUM OF 1.5 ON YIELD STRENGTH

(GROSS STRESS) - METAL

MINIMUM OF 2.0 ON

TSAI-WU CRITERIA - COMPOSITE

LTHD 77

15 JANUARY 1987

LL

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STRUCTURAL ANALYSIS

FMC

ENVIRONMENTS/CONFIGURATIONS

0 CONFIGURATIONS - FIRING, TOW/STOW (WHEELS UP OR DOWN) MODES

0 FIRING MODES - 0° - 72° QE 79,000#
±22.5° TRAVERSE

DYNAMIC INPUTS

0 TOW/STOW MODES (MAJOR)

RAIL TRANSPORT - 15 G FORE/AFT

LAPES DEPLOYMENT - 6G THEN 20 G DOWNWARD

LOW VELOCITY PARACHUTE DEPLOYMENT - 18.5 G DOWNWARD

AIRCRAFT TRANSPORT - 4.5 G DOWNWARD

TRUCK TRANSPORT - BUMP AND SKID (FRONT AND REAR WHEELS)

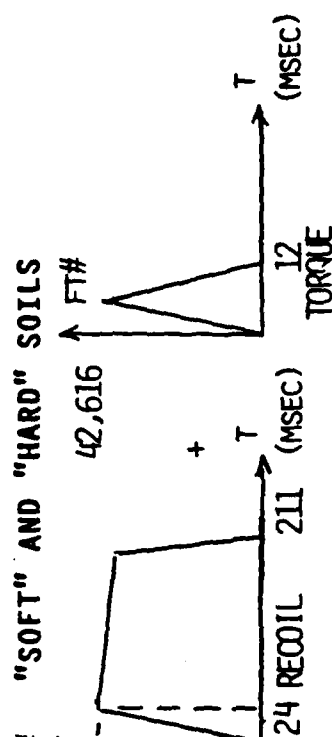
SPEED SHIFT

HELICOPTER TRANSPORT

0 OTHER ENVIRONMENTS:

TEMPERATURE -25°F TO +160°F

VIBRATION - SINE SWEEP AND DWELL



LTHD 7a
15 JANUARY 1987

LL

STRUCTURAL ANALYSIS

FMC

MATERIALS - METAL

MATERIAL	USAGE	E [MPSI]	POISSON'S RATIO [-]	CTE [11/11 ⁰ F] [X10 ⁻⁶]	WEIGHT DENSITY [#/IN ³]	YIELD STRENGTH [KPSI]	% ELONG. [%]	DATA	
								SOURCE	ISSUE
TITANIUM	PLATFORM								
TI-6AL-4V	GIMBAL	16.0	0.31	4.9	0.162	120	13	TIMET	CORP.
ANNEALED	SPADE								
(SHEET OR	BEAM								
PLATE)	FRAME								
AISI	BEAM	29.0	0.30	N/A	0.280	132	17	MATERIALS	REFERENCE
4340 HT	PINS								
(ROD)	TUBE								
	AXLES								
TITANIUM	MUZZLE	17.3	0.30	5.2	0.160	128	12	MATERIAL'S	SELECTOR
TI-6AL-4V	BRAKE								
(CASTING)									
6061-T6									
ALUMINUM	TRAIL	16.0	0.24	7.5	.101	50		DNA	
SI-C 20%	LATTUCE							ARCO	
(TUBE)								MCIAC	

LTHD 79

15 JANUARY 1987

LL

STRUCTURAL ANALYSIS

FMC

MATERIALS - COMPOSITE

0 USAGE: TRAILS, CRADLE

MATERIAL	E1 [MPSI]	E2 [MPSI]	POISSON		CIE	WEIGHT		STRENGTH*	
			RATIO	[-]		DENSITY	[# /IN ³]	TYPE	VALUE
					[11/11/0FX10 ⁻⁶]			[-]	[KPSI]
GRAPHITE/EPOXY									
HERCULES									
AS4/350T6	8.8	8.0	0.20		1.6	0.06		WARP TENSILE	89.3
PLAIN WEAVE	(8.0)	(8.1)						WARP COMP.	67.8
EPOXY PREPREG									
								FILL TENSILE	64.5
								FILL COMP.	55.2
								WARP SHEAR	4.6
								FILL SHEAR	5.9
CORE									
NOMEX HONEYCOMB	(.06)	-	-		-	6.0[#-FT ³]		COMPRESSIVE	1.1
FROM HEXCEL								L-SHEAR	0.37
-10-1/8-6.0								W-SHEAR	0.20
ADHESIVE									
AMERICAN CYNAMIDE	-	-	-		-	-		TENSILE SHEAR	4.3
FM 300M FILM									
-.030 #/FT ²									

0 SOURCE OF DATA: BOEING, McDONNELL AIR, HEXCEL

0 NOTES: (): COMPRESSIVE VALUE 0 PROPERTIES GOOD FOR TEMPERATURE ENVIRONMENT

* : BASIS OF 250°F WITH "A" ALLOWABLE

LTHD 80

15 JANUARY 1987

LL

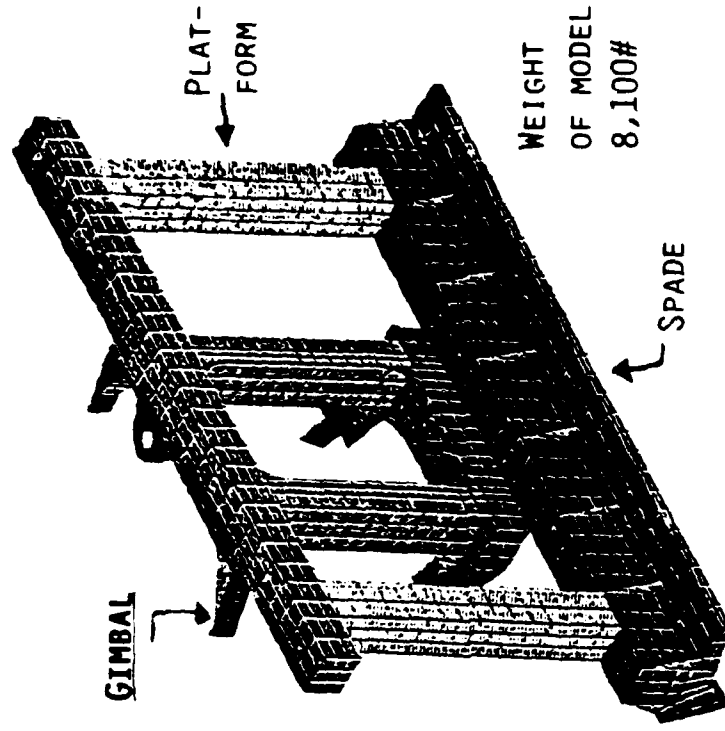
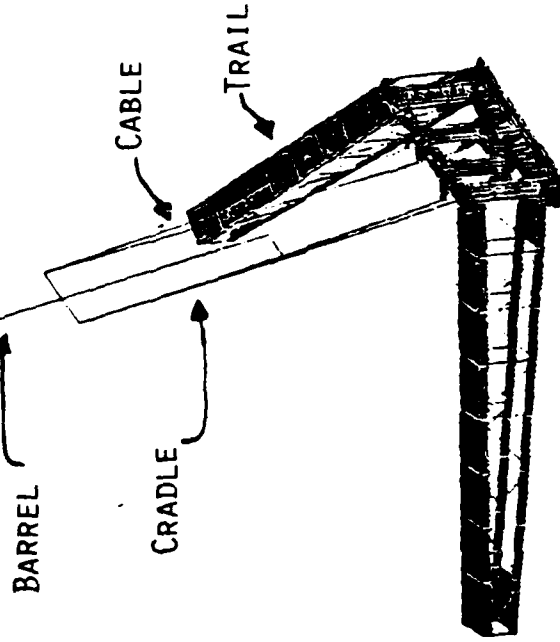
80

STRUCTURAL ANALYSIS

FMC

SYSTEM MODEL

OVERALL MODEL



WEIGHT
OF MODEL
8,100#

- 0 ANALYSIS FEA - TRANSIENT ANALYSIS
- 0 FOUR FIRING POSITIONS
(NOTE: 72° QE, 0° T SHOWN)
- 0 PROOF FIRING LOAD (79,000# RECOIL
AND 48,000 FT # TIME PROFILES INPUT)
- 0 "HARD SOIL" CONDITIONS - SPADE
FIXED, TRAILS FREE

- 0 MODEL ACCURACY: DETAILED STRESSES
IN GIMBAL AND PLATFORM EXCEPT
AT INTERCONNECTIONS

GROSS STRESS IN SPADE AND TRAIL

LTHD 21

15 JANUARY 1987

LL

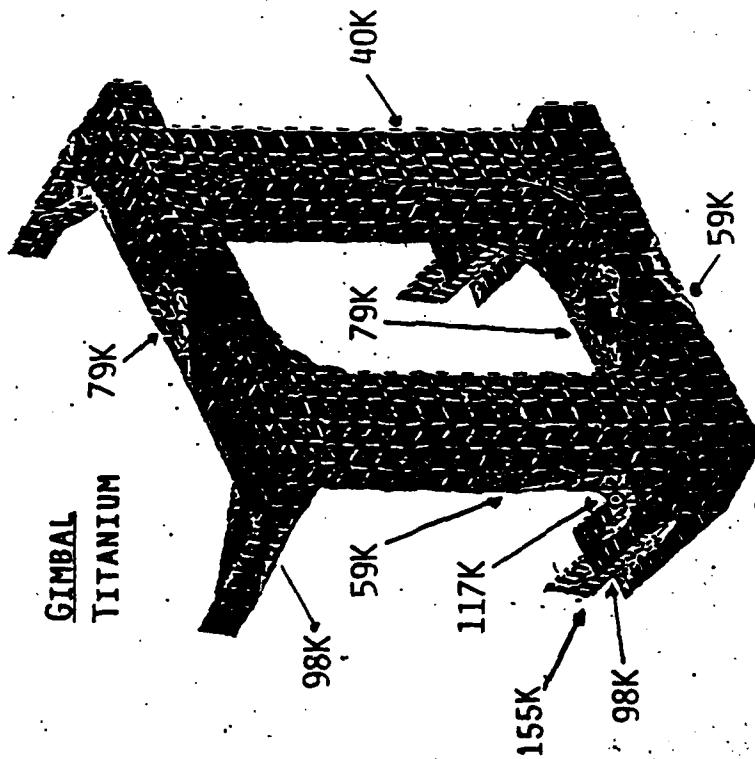
8

STRUCTURAL ANALYSIS

FMC

SYSTEM RESULTS

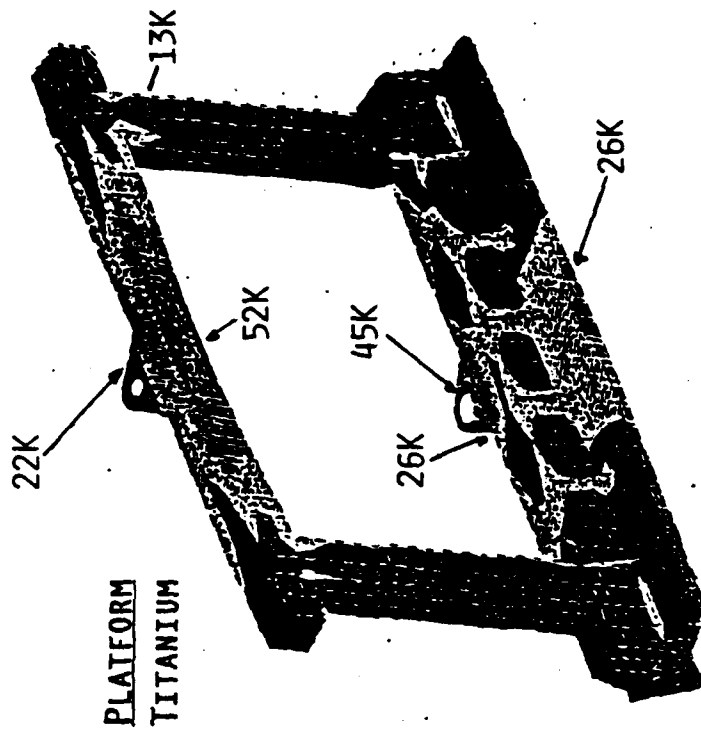
NOTE: VON-MISES STRESS SHOWN AT TIME = .031 SEC



0 MINIMUM S.F.* GIMBAL = 1.0
PLATFORM = 2.3
SPADE = 4.6

0 GIMBAL ARMS NEED STRENGTHENING.
SPADE/PLATFORM ARE ADEQUATE

*FOR GROSS STRESS



FIRING LOAD: 72° QE AND 0° T

LTHD 82

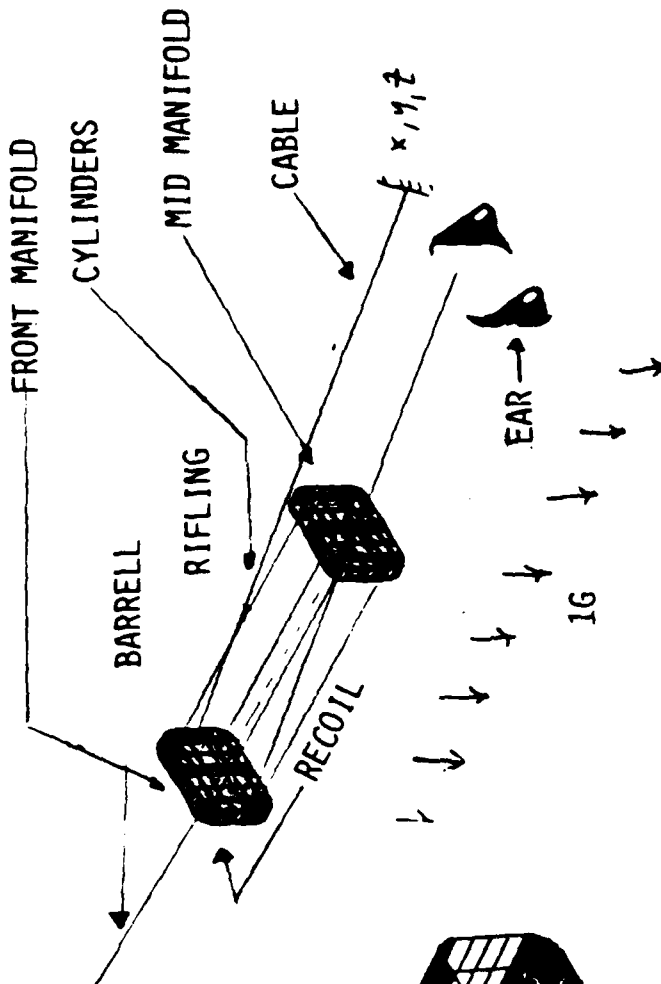
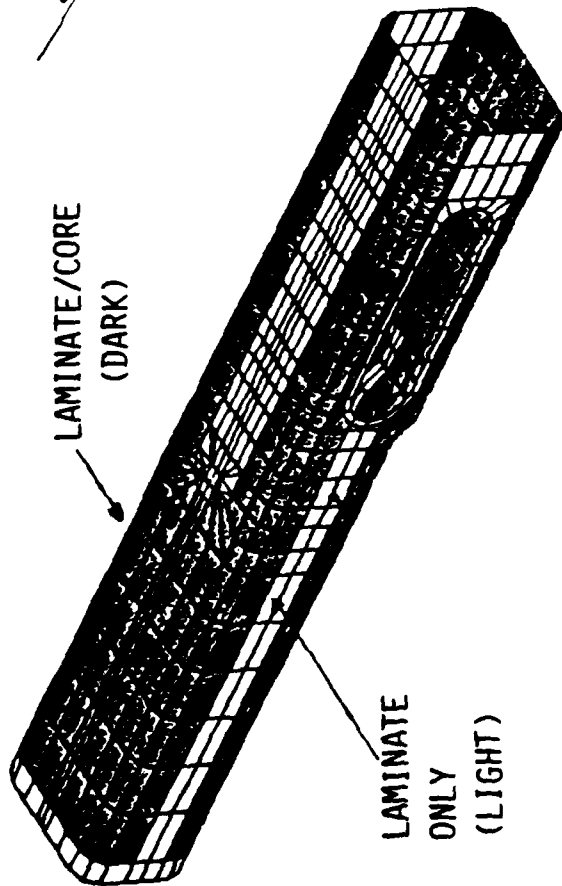
LL

15 JANUARY 1987

STRUCTURAL ANALYSIS

FMC

CRADLE MODEL



- 0 ANALYSIS FEA - STATIC ANALYSIS.
- 0 COMPOSITE CRADLE, KEVLAR CABLE.
- 0 PROOF FIRING LOAD (79,000# RECOIL,
AND 48,000 FT-# RIFLING TORQUE).
- ALSO 1G DOWNWARD.
- 0 B.C.
- CABLE SUPPORTED X,Y,Z; FREE ROTATE
- EARS SUPPORTED X,Y.; FREE ROTATE
- 0 FRONT MANIFOLD COMPRESSES CRADLE,
ATTACHED TO CRADLE X,Y,Z AT BOTTOM.
- 0 "SHEARED" PROPERTIES

0 MODEL ACCURACY:
GROSS STRESS EXCEPT
EAR STRESS APPROXIMATE

LTHD 83
15 JANUARY 1987
LL

STRUCTURAL ANALYSIS

FMC

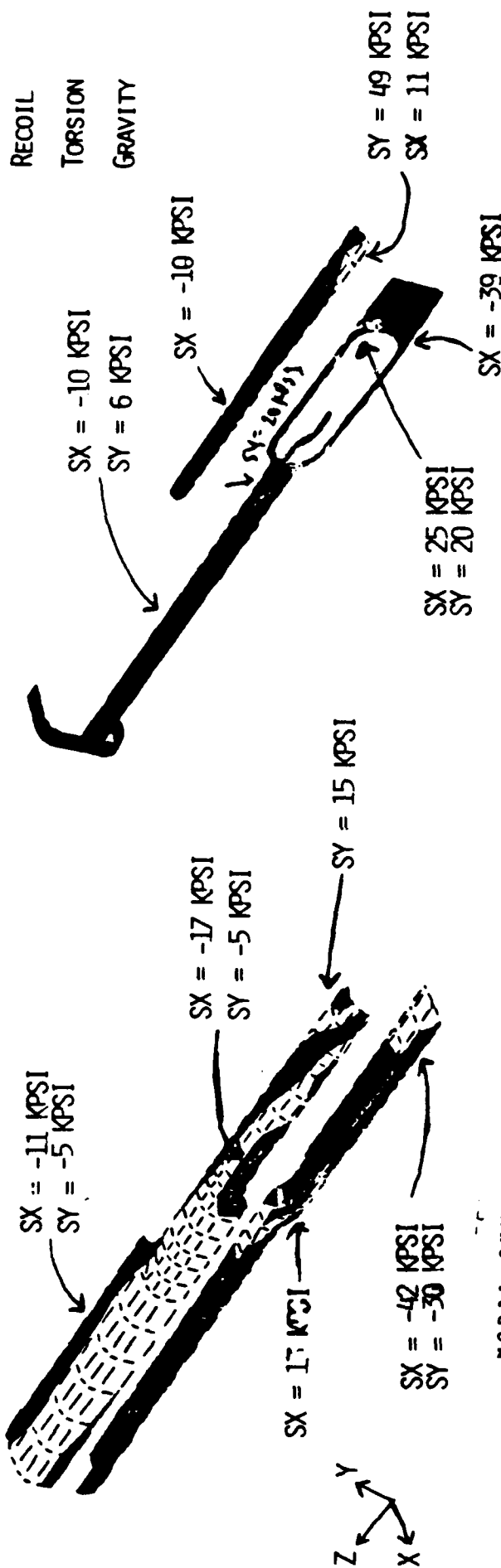
CRADLE RESULTS

NOTE: ONLY HALF OF STRUCTURE SHOWN

GR - EPOXY AND CORE AREAS

GR - EPOXY ONLY

LOAD: STATIC



MODAL SUMMARY

MODE #	FREQUENCY	DIRECTION	DESCRIPTION
1	2.55	Y	CANTILEVER
2	3.11	X	CANTILEVER
3	4.34	X	CABLES
4	4.35	Y	CABLES
5	4.35	Y	CABLES
6	4.36	Y	CABLES
7	8.56	Y	2ND BENDING
8	12.0	Z	TORSION
9	12.4	X-Z	Torsion Bending
10	31.2	Y	BENDING

- 0 TORSIONAL DISPLACEMENT = 3.5°
- 0 COMPRESSIONAL DISPLACEMENT = -.52 IN.
- 0 SMALLER MODEL VALIDATED MODE SHAPES AND GROSS STRESS
- 0 DYNAMIC RESULTS IN PROCESS
- 0 TSAI-MU VALUES BEING CALCULATED

LTHD 84

15 JANUARY 1987

U.

84

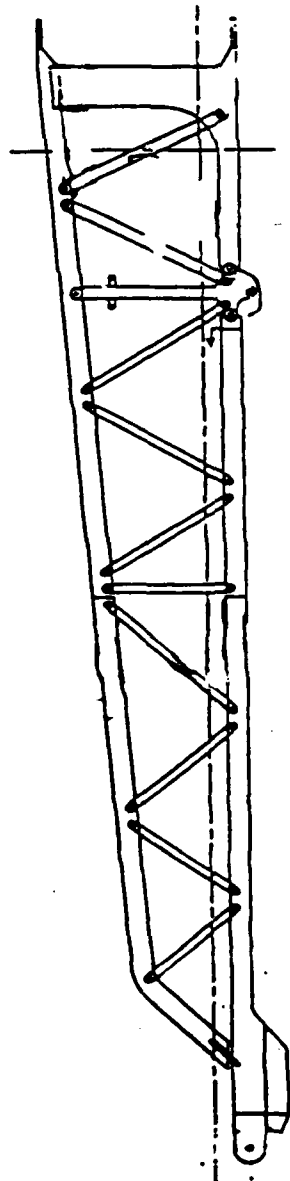
STRUCTURAL ANALYSIS

FMC

TRAIL MODEL

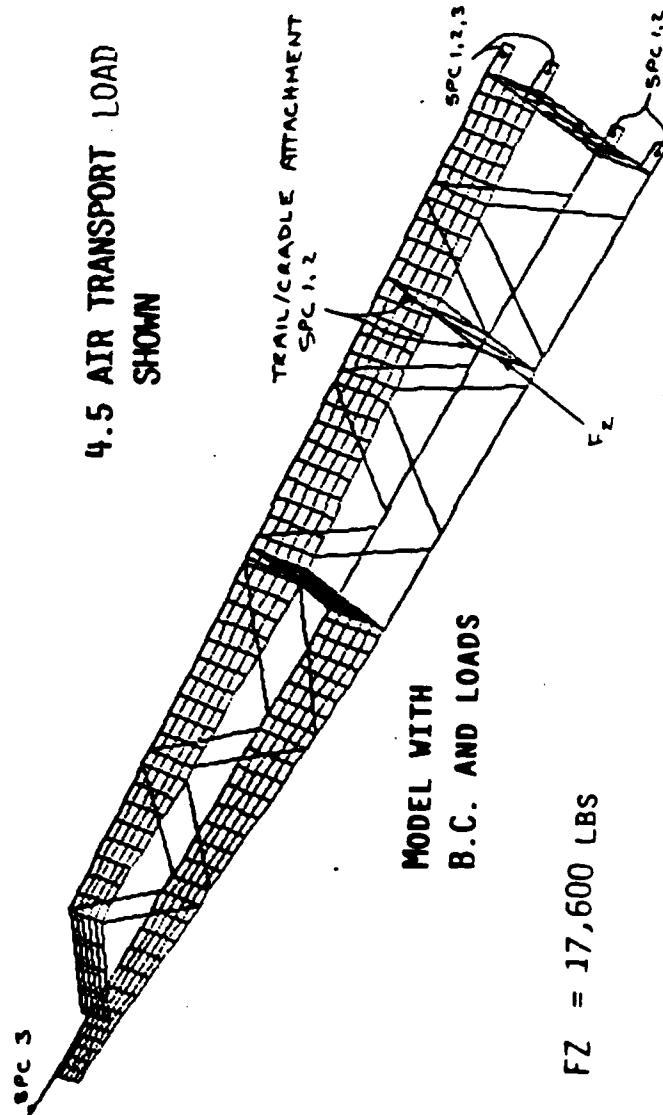
GEOMETRY

WEIGHT: 325#



- 0 NASTRAN FEA -
STATIC ANALYSIS
- 0 COMPOSITE, TITANIUM AND
AL-SI-CARBIDE MATERIALS
- 0 TWO TRANSPORTATION
MODES AND FIRING
LOAD ANALYZED
WORST: 4.5G AIR
TRANSPORT

4.5 AIR TRANSPORT LOAD SHOWN



MODEL WITH B.C. AND LOADS

FZ = 17,600 LBS

- 0 MODEL ACCURACY:
GROSS STRESSES IN BEAM
AND PLATE ELEMENTS

LTHD 85
15 JANUARY 1987
LL

STRUCTURAL ANALYSIS

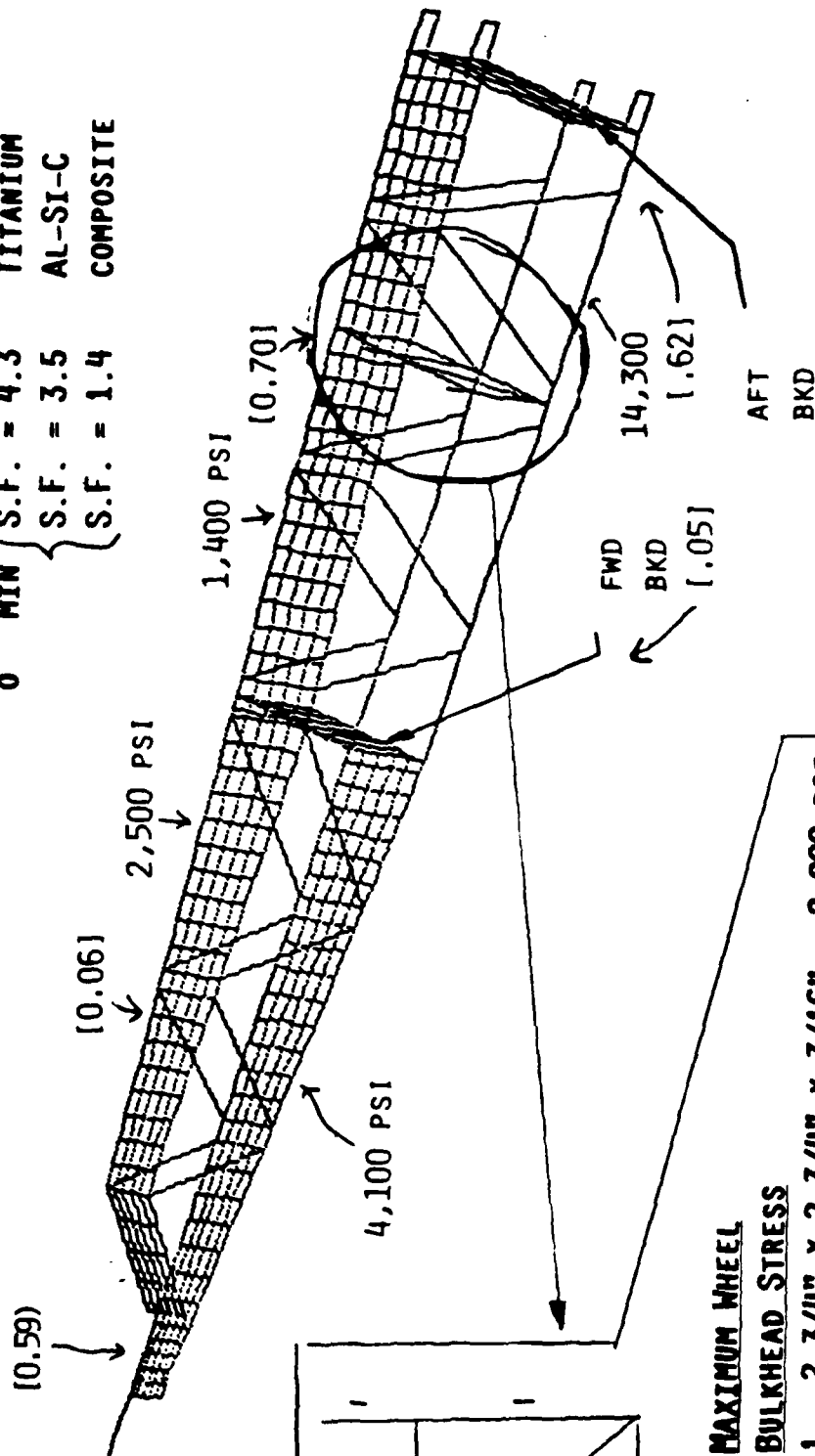
FMC

TRAIL RESULTS

NOTE: [T-W] = TSAI-WU VALUE

0 MIN { S.F. = 4.3
S.F. = 3.5
S.F. = 1.4

TITANIUM
AL-SI-C
COMPOSITE



MAXIMUM WHEEL

BULKHEAD STRESS

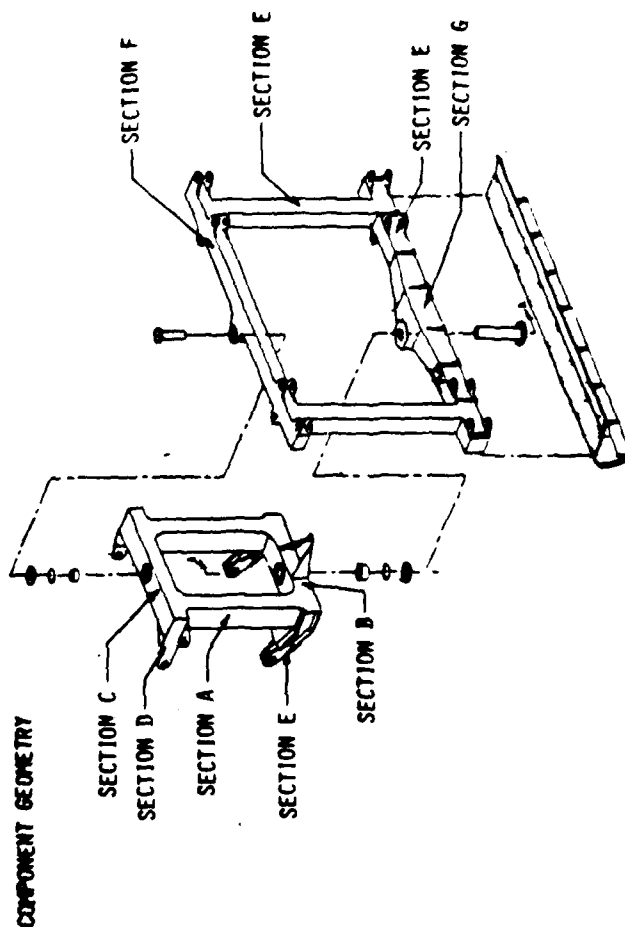
1. 2 3/4" x 2 3/4" x 3/16" - 2,800 PSI
2. 2" x 2 3/4" x 3/16" - 2,100 PSI
3. TRAIL/CRADLE CONNECTORS - 2,800 PSI

LTHD 86
15 JANUARY 1987
LI

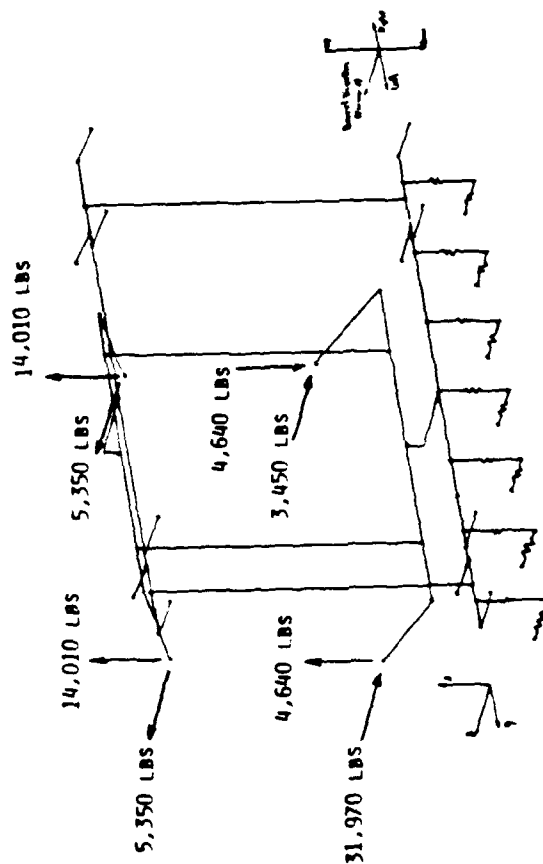
STRUCTURAL ANALYSIS

FMC

PLATFORM/GIMBAL SPADE MODEL



FINITE ELEMENT MODEL - GIMBAL AND PLATFORM



NOTE: TRAIL FORCES NOT SHOWN

TRAIL MODEL NOT SHOWN

- 0 NASTRAN FEA - STATIC ANALYSIS
- 0 TITANIUM COMPONENTS
- 0 FOUR FIRING ORIENTATIONS
- 0 WORST: 72° QE AND 22.5° T
- 0 "SOFT" SOIL BOUNDARY CONDITIONS
- 0 MODEL ACCURACY: GROSS STRESSES IN BEAM ELEMENTS

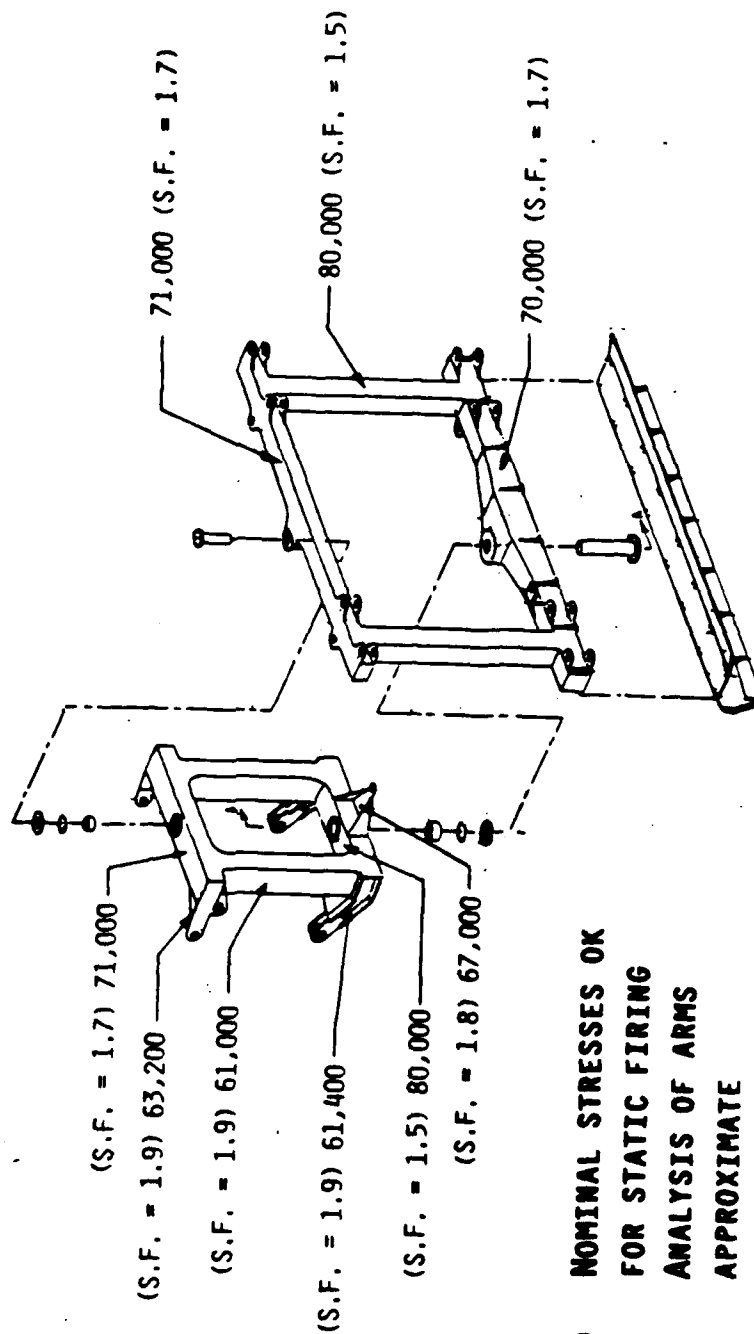
LTHD 87
15 JANUARY 1987
LL

STRUCTURAL ANALYSIS

FMC

PLATFORM/GIMBAL SPADE RESULTS

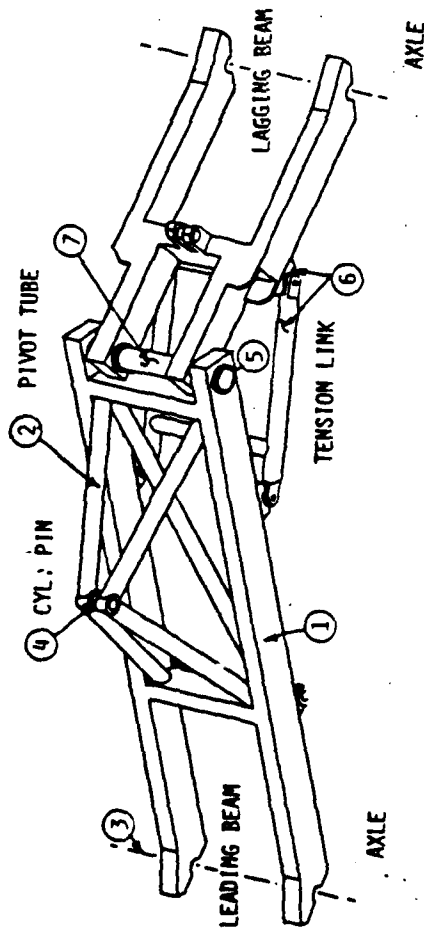
HIGHEST STRESS (PSI) VALUES AND SAFETY FACTORS COMBINED STRESSES (CASE OF 72° QE AND 22.5° T)



0 NOMINAL STRESSES OK
FOR STATIC FIRING
0 ANALYSIS OF ARMS
APPROXIMATE

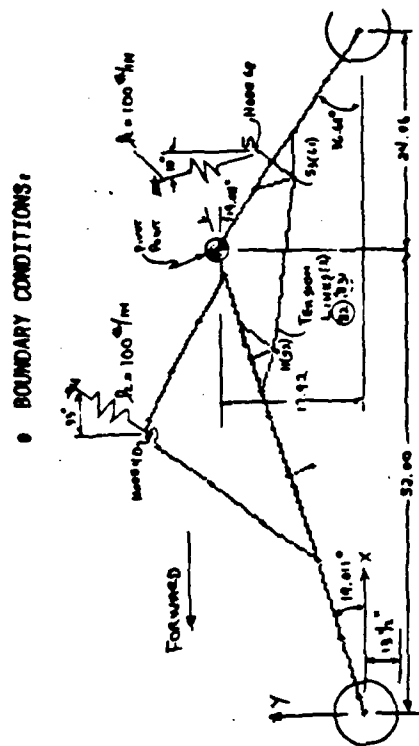
LTHD 88
15 JANUARY 1987
LL

COMPONENT GEOMETRY



O - BEAM CROSS-SECTION PROPERTIES

- 0 IMAGES 3D FEA-STATIC ANALYSIS
0 THREE TRANSPORTATION MODES CONSIDERED
WORST: 4.5 G AIRCRAFT
0 SPRINGS USED TO CONNECT TO TRAIL AND CRADLE
AND TO STABILIZE MODEL
0 MODEL ACCURACY: GROSS STRESSES IN BEAM ELEMENTS



NOTE: 2D VIEW

LTHD 89 68

15 JANUARY 1987

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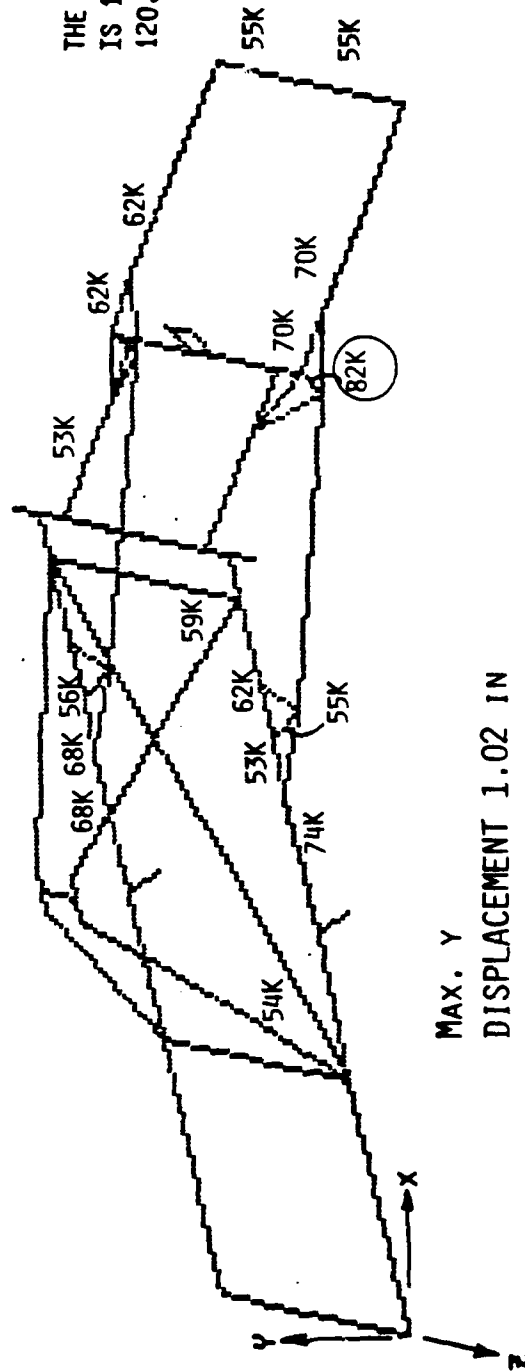
STRUCTURAL ANALYSIS

FMC

LEADING/LAGGING, BEAM RESULTS

NOTE, ONLY STRESSES OVER 50K ARE SHOWN
COMBINES STRESSES, Y - BENDING
Z - BENDING
AXIAL

4.5G LOAD AIRCRAFT LANDING



THE MINIMUM FACTOR OF SAFETY FOUND
IS 1.46, BASED ON A YIELD OF
120,000 FOR TITANIUM (CIRCLED)

- 0 NOMINAL STRESSES ARE OK FOR FRAME STRUCTURE
- 0 FURTHER ANALYSIS REQUIRED FOR OTHER PARTS OF WHEEL ASSEMBLY
- 0 DYNAMIC ANALYSIS NEEDED TO PREDICT MODE FREQUENCY FOR TOWING MODE

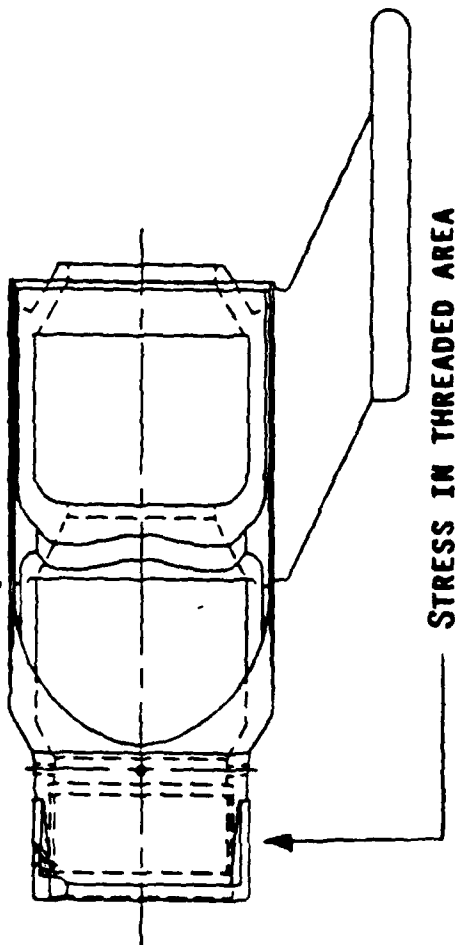
LTHD 90
15 JANUARY 1987
LL

STRUCTURAL ANALYSIS

FMC

MUZZLE BRAKE ANALYSIS

- 0 HAND CALCULATIONS
- 0 TITANIUM CASTING
- 0 FIRING MODE ANALYSIS
LOADS (AT BRAKE)
-INTERNAL BARREL PRESSURE
(11,000 PSI)
-TEMPERATURE OF BARREL
(+250° F)
-RECOIL "G" LOAD
(171*G-M198,300G LTHD)



RESULTS

	<u>M198</u>	<u>LTHD</u>
HOOP STRESS	21.100	13.300
-PRESSURE		
HOOP STRESS	20.700	13.800
-TEMPERATURE		
G * W	42KIPS	55KIPS

* ESTIMATED

- 0 FEASIBILITY OF BRAKE
DETERMINED BY COMPARISON

<u>M198</u>	<u>LTHD</u>	
<u>STEEL</u>	<u>TI</u>	
250#	141# (190# WITH LUNETTE)	
8.3	5.2	
CTE		
WEIGHT		
STRENGTH	132K PSI	128K PSI

LTHD 9/
15 JANUARY 1987
LL

STRUCTURAL ANALYSIS

FMC

SUMMARY OF RESULTS - FEA ANALYSIS

<u>COMPONENT</u>	<u>PN</u>	<u>MATERIAL</u>	<u>HEIGHT</u> <u>[#]</u>	<u>WORST</u> <u>CASE</u> <u>LOAD</u>	<u>MIN.*</u> <u>S.F.</u>	<u>COMMENT</u>
CRADLE	5831	COMPOSITE	350	FIRING	TBD	NEED STRENGTHENING
TRAIL	5840	COMPOSITE TITANIUM AL-SI-C	325	TRANSPORTATION	1.4	NEED STRENGTHENING
PLATFORM	5801	TITANIUM	354	FIRING	1.5	PROPER STRENGTH
GIMBAL	5811	TITANIUM	248	FIRING	1.0	STRENGTHEN ARMS
LEADING/ LAGGING BEAM	5710	TITANIUM (FRAME)	100	TRANSPORTATION	1.5	PROPER STRENGTH

NOTES: * FOR GROSS STRESS

LTHD 92
15 JANUARY 1987
LL



STRUCTURAL ANALYSIS

SUMMARY OF RESULTS - HAND CALCULATION ANALYSIS

<u>COMPONENT</u>	<u>PN</u>	<u>MATERIAL</u>	<u>WEIGHT [EA.]</u> [#]	<u>Worst CASE LOAD</u>	<u>S.F.</u>	<u>COMMENT</u>
MUZZLE BRAKE	5766	TITANIUM	190	THERMAL	9.2	PRESSURE AND RECOIL CONSIDERED
BARREL COLLAR -REAR	5781-001	4340 STEEL	24	THERMAL	2.1	PRESSURE AND RECOIL CONSIDERED
BARREL COLLARS -FRONT	5781-002	6061 T6A1 20% SI-C	20	THERMAL	1.5	PRESSURE ALSO CONSIDERED
RAIL	6016-001	6061 T6A1 20% SI-C	156	RECOIL	1.2	BEARING STRESS
RAIL/COLLAR BOLTS	6002-018	STEEL	0.35	RECOIL	3.0	-
BARREL/COLLAR KEYS	6022-001	STEEL	0.60	TORQUE	1.6	SHEAR STRESS

NOTES: FIRING LOADS ONLY

LTHD 93
15 JANUARY 1987
LL

STRUCTURAL ANALYSIS

FMC

CONCLUSIONS

- 0 MOST MAJOR COMPONENTS ARE APPROACHING OPTIMUM DESIGN
- 0 ADDITIONAL STRENGTHENING REQUIRED FOR:
 - CRADLE (EARS)
 - GIMBAL (UPPER AND LOWER ARMS)
 - TRAILS (UPPER FRAME)
- 0 PROBABLE STRENGTHENING REQUIRED AT INTERCONNECTION POINTS
- 0 DATA AVAILABLE TO SIZE INTERCONNECTS
- 0 POSSIBLE WEIGHT REDUCTION:
 - CRADLE (BETWEEN MANIFOLDS) - 50#
 - GIMBAL (MAJOR BOX SECTIONS) - 25#
 - PLATFORM (MAJOR BOX SECTIONS) - 25#
 - TRAILS (LATTICE BEAMS, BULKHEAD) - 50#

LTMD 94
15 JANUARY 1987

LL

STRUCTURAL ANALYSIS

FMC

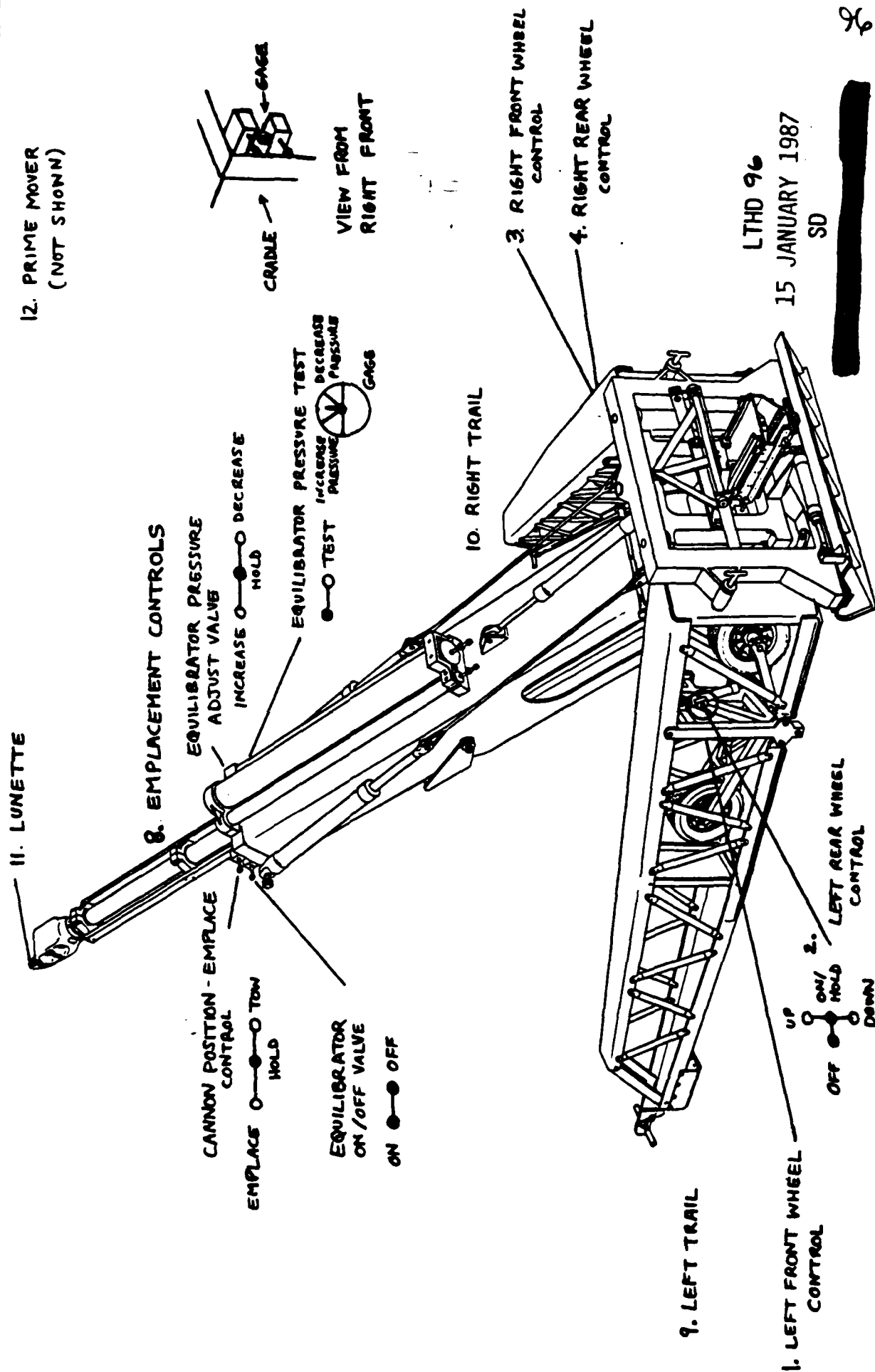
ANALYSIS PLANS

- 0 CONTINUE WEIGHT AND STRENGTH OPTIMIZATION ON MAJOR COMPONENTS
- 0 CONTINUE ANALYSIS OF INTERCONNECTIONS
- 0 DETERMINE VIBRATION MODE/FREQUENCIES - TOW AND FIRING MODES

LTHD 95
15 JANUARY 1987
LL

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12. PRIME MOVER
(NOT SHOWN)



LTHD 96
15 JANUARY 1987
SD


96

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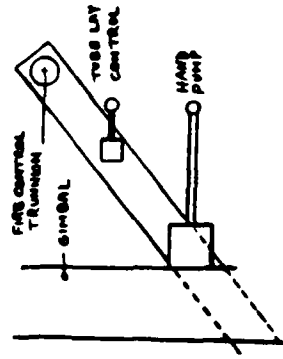
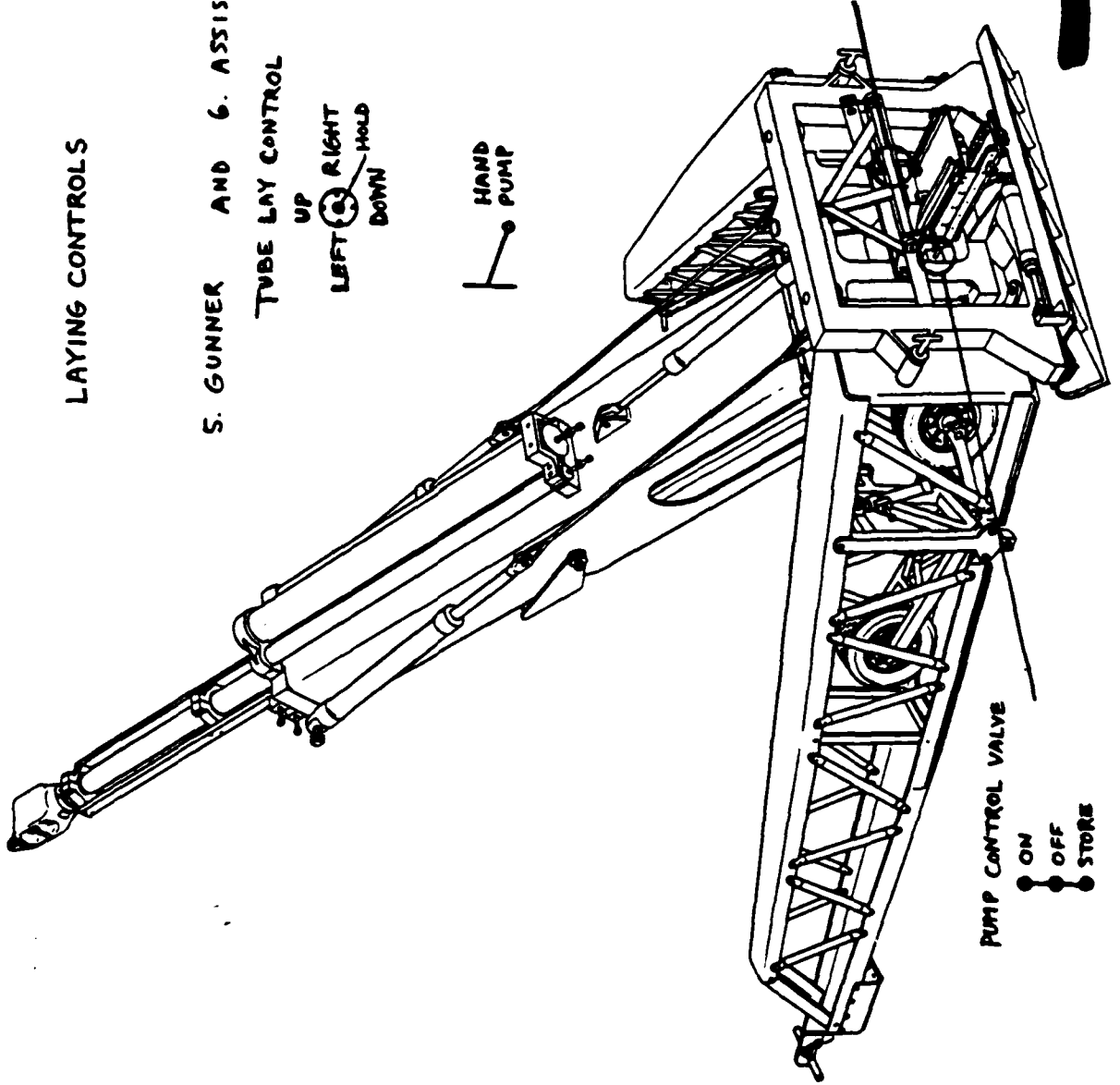
LAYING CONTROLS

5. GUNNER AND 6. ASSISTANT GUNNER

TUBE LAY CONTROL

UP
LEFT  RIGHT
DOWN HOLD

HAND PUMP

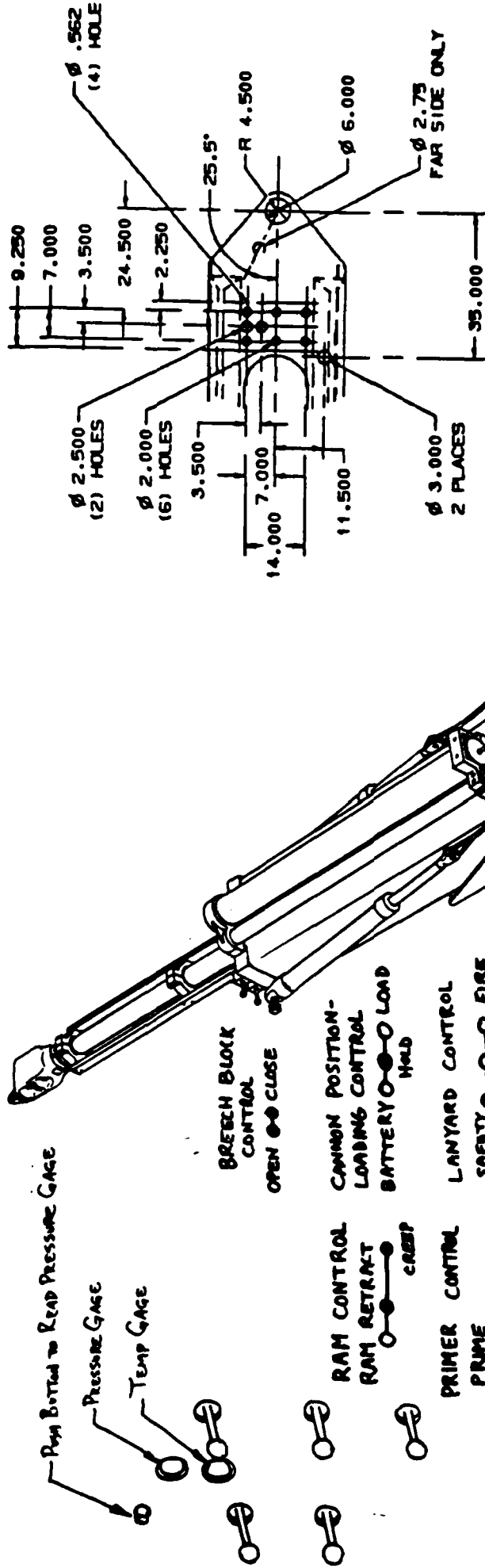


LTHD 97
15 JANUARY 1987
SD

97

FMC

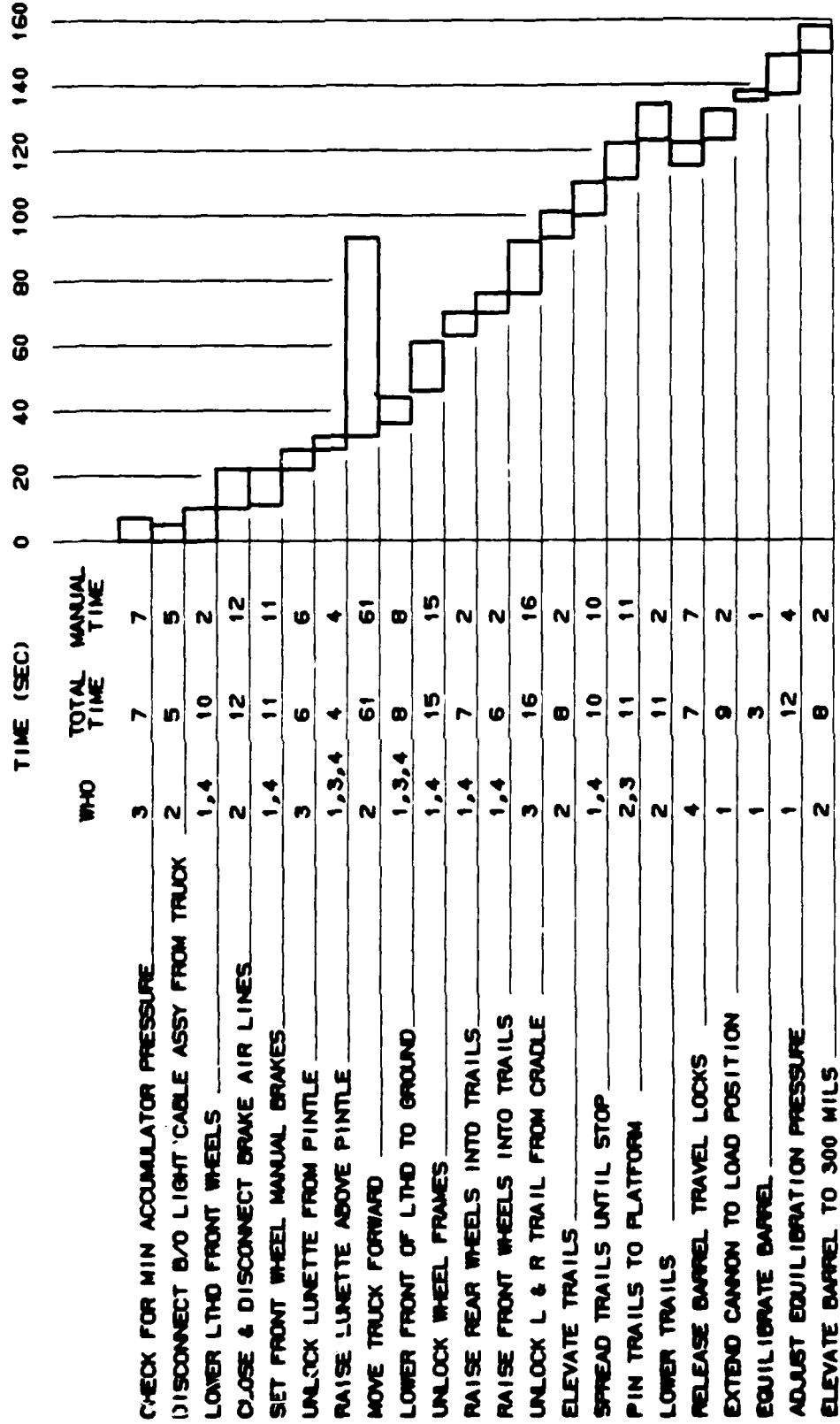
7. LOADING CONTROLS



LTHD 98
15 JANUARY 1987
SD

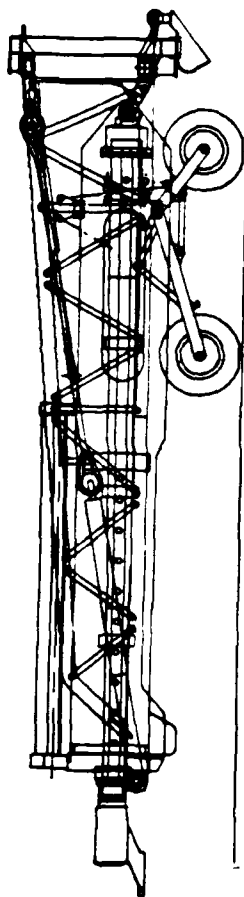
FMC

FMC LTHD EMPLACEMENT TIMELINE

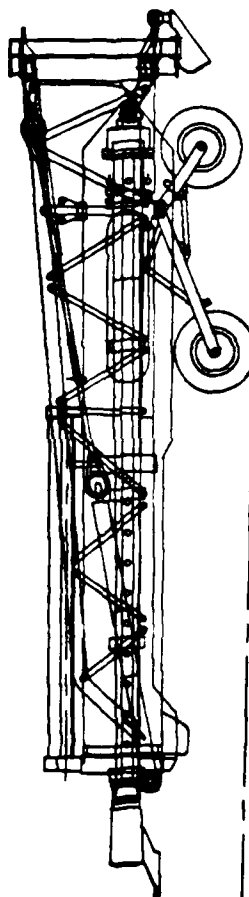


FMC LTHD - EMPLACEMENT PROCEDURE

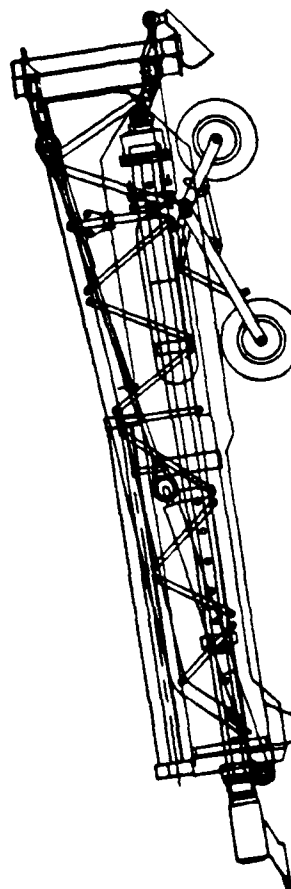
FMC



TOW POSITION



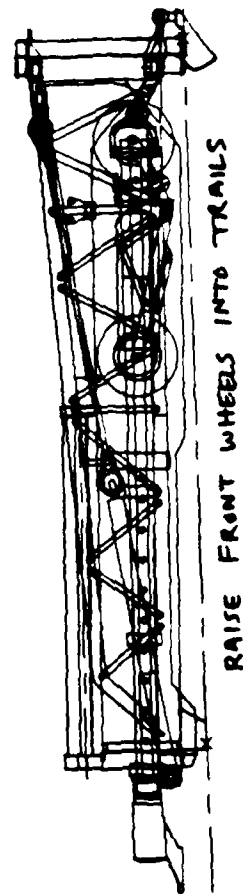
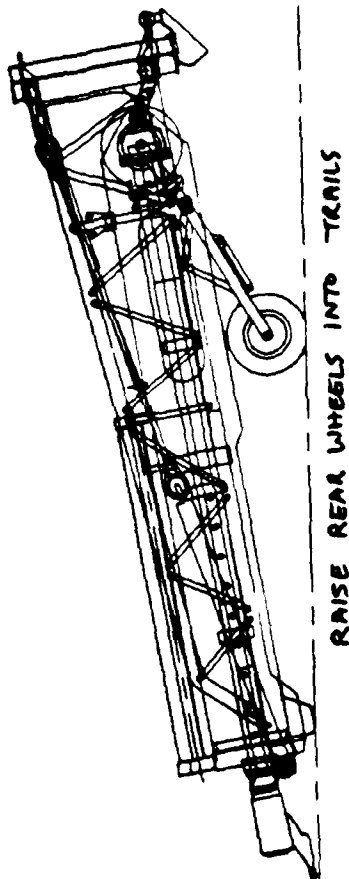
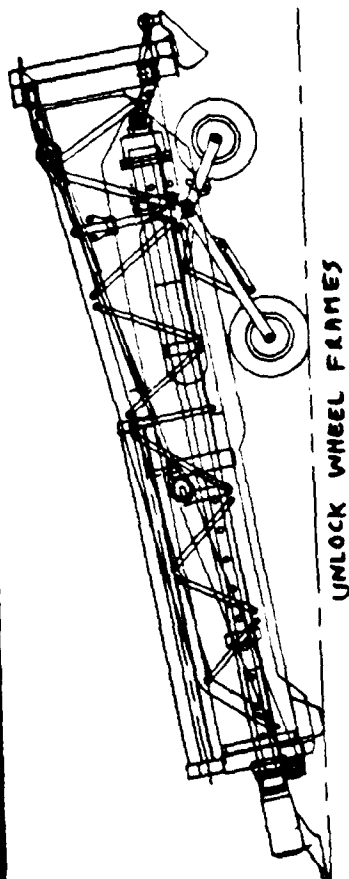
LOWER LTHD FRONT WHEELS



LOWER FRONT OF LTHD TO GROUND

LTHD 100
15 JANUARY 1987
SD

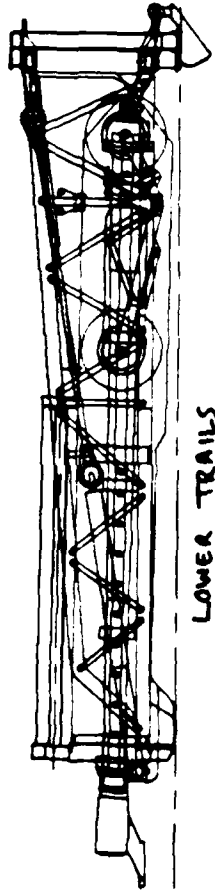
FMC



LTHD 101
15 JANUARY 1987
SD

FMC

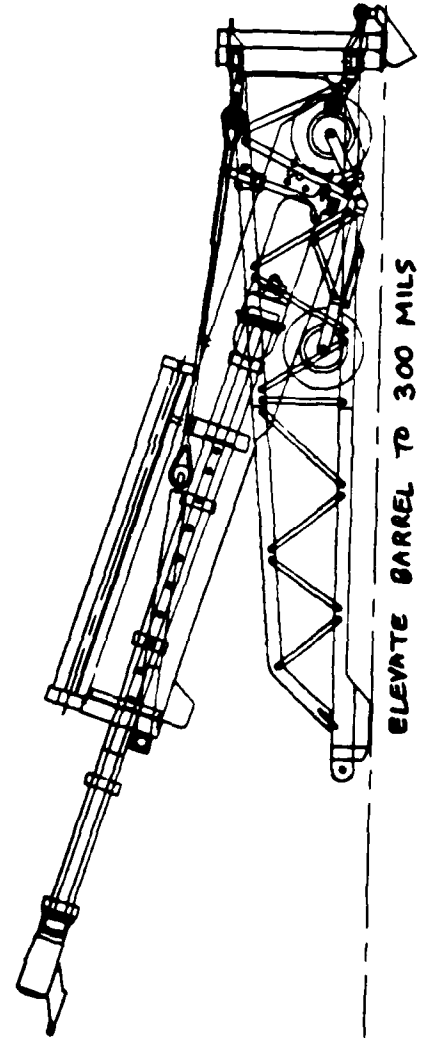
NOT SHOWN - ELEVATE TRAILS
SPREAD TRAILS
PIN TRAILS TO PLATFORM



LOWER TRAILS



EXTEND BARREL TO LOAD POSITION



ELEVATE BARREL TO 300 MILS

LTHD 102
15 JANUARY 1987
SD

FMC

TIMELINE FOR MAX RATE OF FIRE - BELOW 600 MILS

1.3 SECONDS IS AVERAGE TIME PER ROUND.
ACTUAL TIME IS 5.2 SECONDS FOR
SWABBING AFTER EVERY 4th ROUND.

	WHO	TIME (SEC) TOTAL TIME	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RECOIL	1	.22																
COUNTER RECOIL TO LOAD POSITION	1	1.78		1.78														
OPEN BREECH	1	1.0				1.0												
SWAB CHAMBER	1	1.3					1.3											
RAM AND RETRACT	1	2.8						2.8										
LIFT CHARGE TO WINDOW	1	1.5							1.5									
POSITION CHARGE IN BREECH	1	2.5								2.5								
CLOSE BREECH	1	1.6									1.6							
MOVE BARREL TO BATTERY	1	1.9										1.9						
CYCLE PRIMER AUTO LOADER	1	1.8											1.8					
FIRE PROJECTILE	1	.5												.5				
STAGE PROJECTILE	3	15.0																
STAGE BAG CHARGE	2	15.0																

LTHD 103

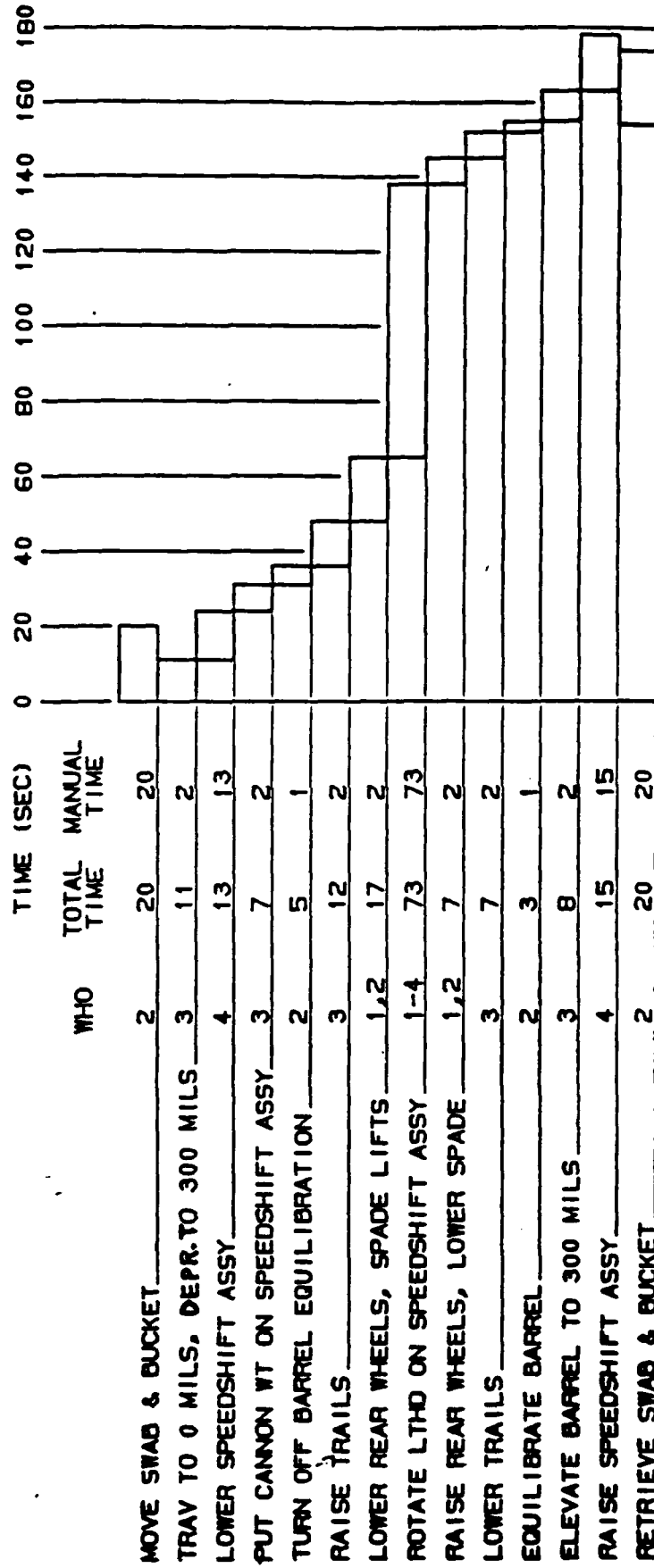
15 JANUARY 1987

SD

103

FMC

SPEEDSHIFT TIMELINE



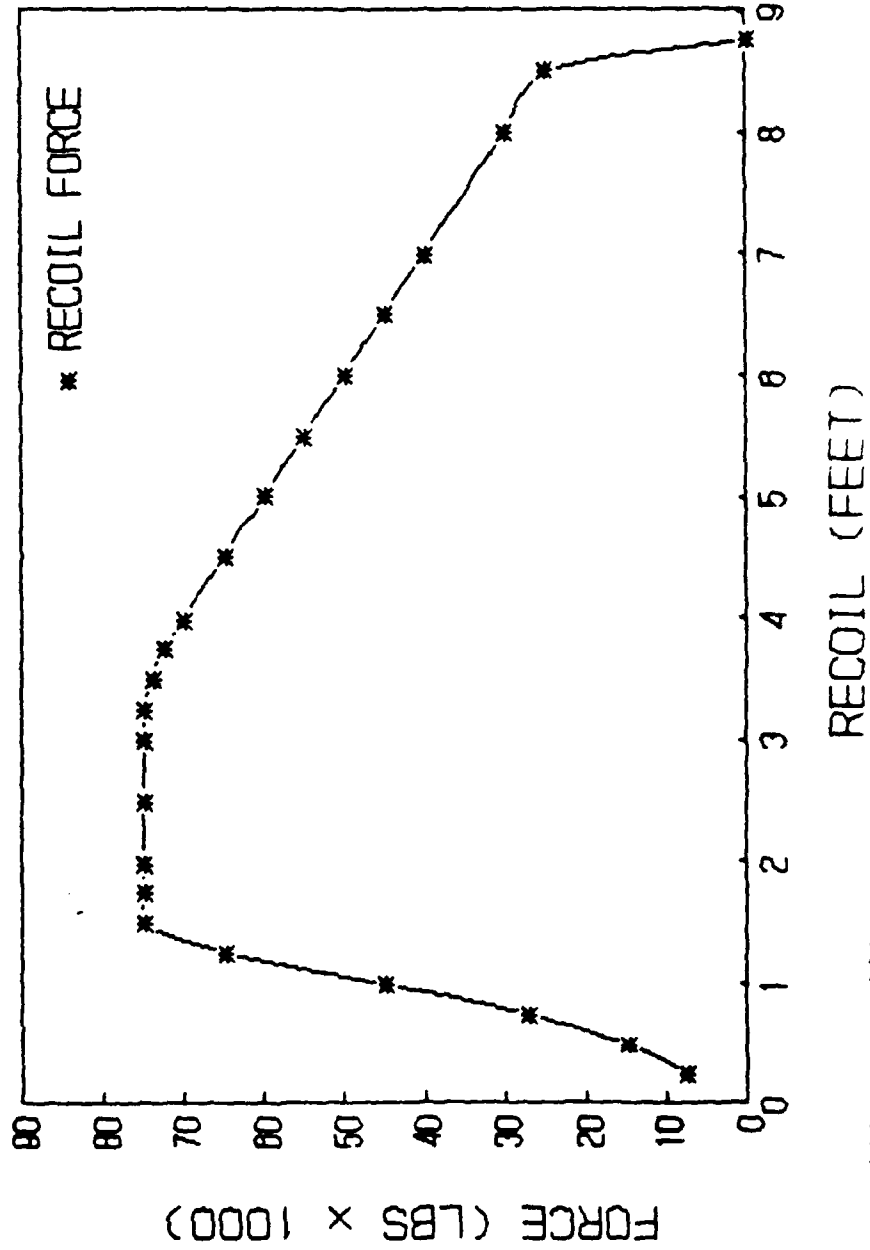
LTHD 104
15 JANUARY 1987
SD

104

FMC

LTHD RECOIL FORCE

ZONE 8-S



LTHD 105
15 JANUARY 1987
.J1

105

[illegible]

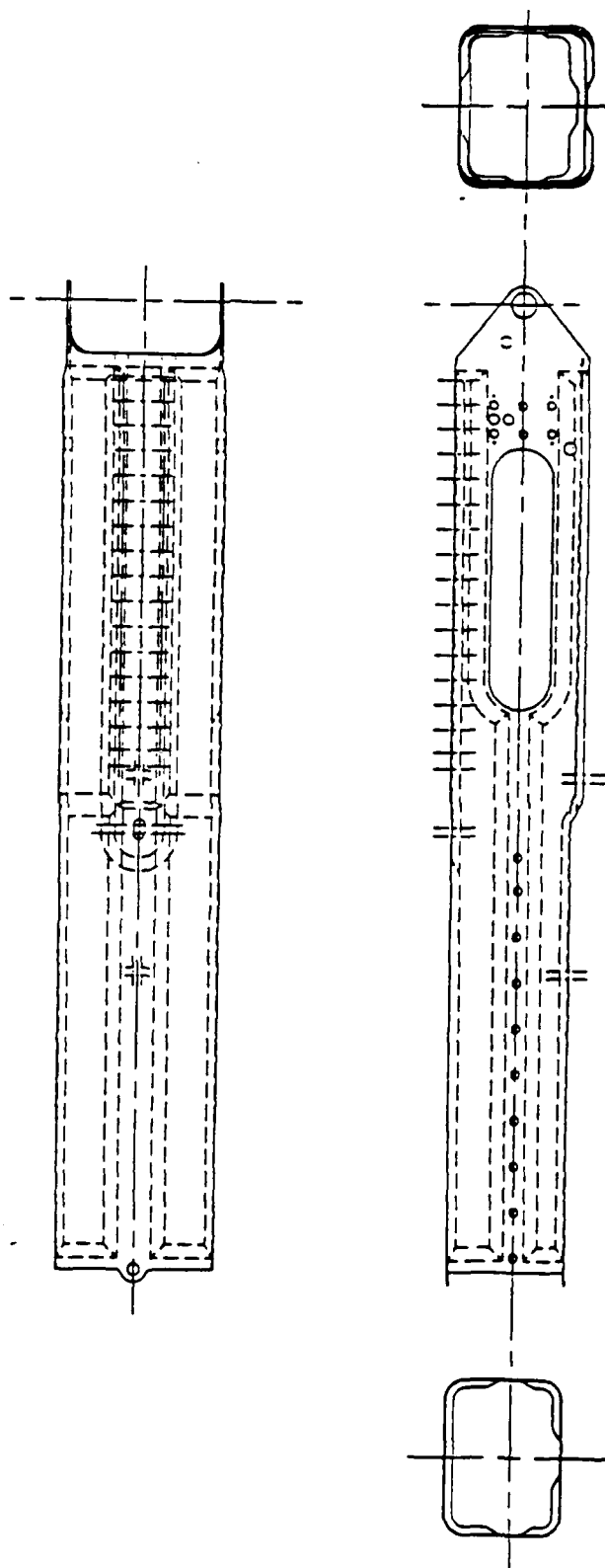
15 JANUARY 1987

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CAO STATUS USED 07/01/19 NEW 17 14708

FMC

CRADLE



LTMD 107
15 JANUARY 1987
TR

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FMC

GRAPHITE EPOXY PROPERTIES

HERCULES A193-P/3501-6

250°F/WET DATA

0° TENSILE STRENGTH	89.3 KSI
0° TENSILE MODULUS	8800 KSI
90° TENSILE STRENGTH	64.5 KSI
90° TENSILE MODULUS	8000 KSI
0° COMPRESSIVE STRENGTH	67.8 KSI
0° COMPRESSIVE MODULUS	8000 KSI
SHEAR STRENGTH	5.9 KSI
POISSON'S RATIO	.2

LTHD 100

15 JANUARY 1987

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FMC

Composite Fabric

Hercules A193-P/3501-6

Data From:

Boeing Composite Design Handbook
D6-44714

CTE	1.6x10E-6 in/in/F
Poissons Ratio	.2
Density	.06 FCI

LTHD 109
15 JANUARY 1987
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CORE MATERIAL

MATERIAL	DENSITY (PCF)	COMPRESSIVE STRENGTH (PSI)	COMP. MOD (KSI)	SHEAR STRENGTH (PSI)	SHEAR MOD. (KSI)
NOMEX					
ARIMID FIBER/ PHENOLIC	6.0	1125	60	200-370	6-13
BALSA WOOD	6.0	750	330	158	14.45

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15 JANUARY 1987
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Honeycomb Adhesive

American Cyanamid
FM 300M

.030 PSF

160 F

Tensile Shear 4335 PSI

LTHD III

15 JANUARY 1987

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TITANIUM SHIMS

Ti-15-3

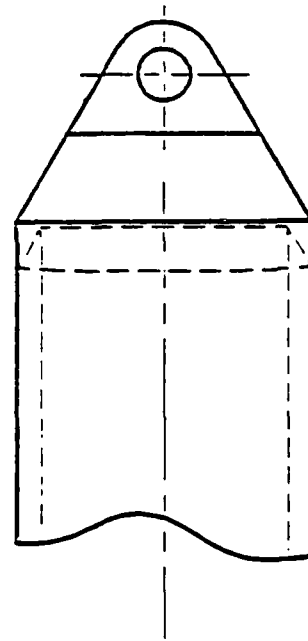
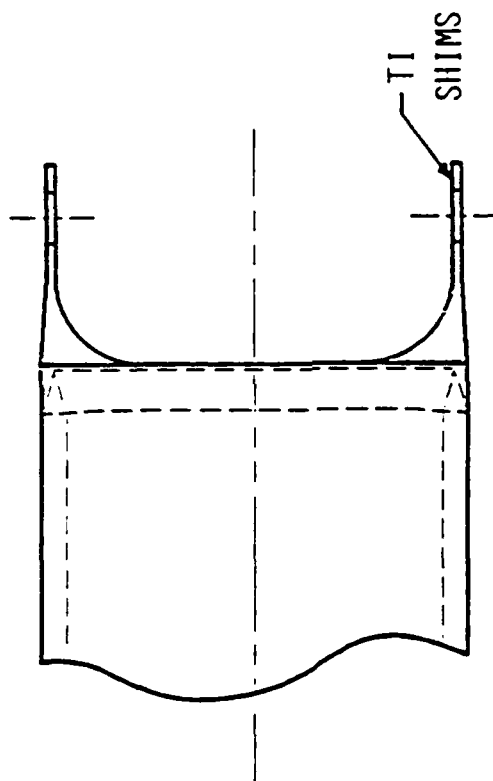
DENSITY	0.172 PCI
MODULUS	12 MSI
CTE	5.4×10^{-6} IN/IN/°F
TENSILE STRENGTH	112 KSI

LTHD 112
15 JANUARY 1987
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FMC

TRUNNION



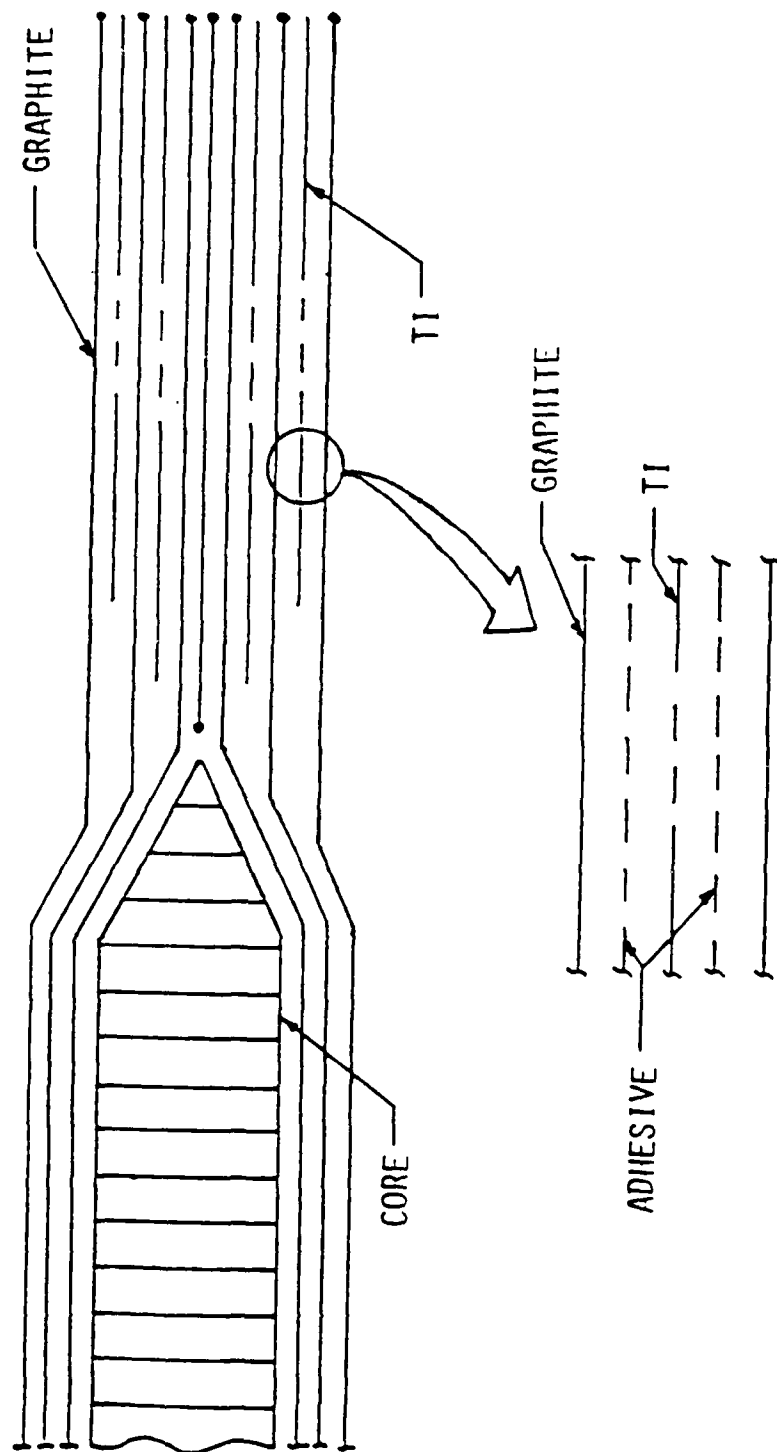
LTHD 113
15 JANUARY 1987

TR

113

FMC

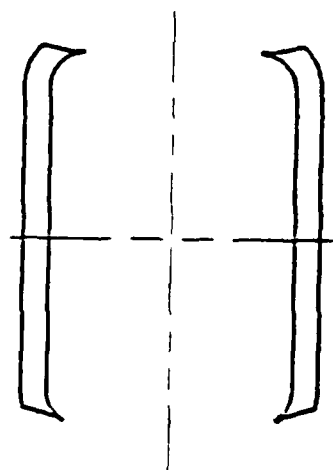
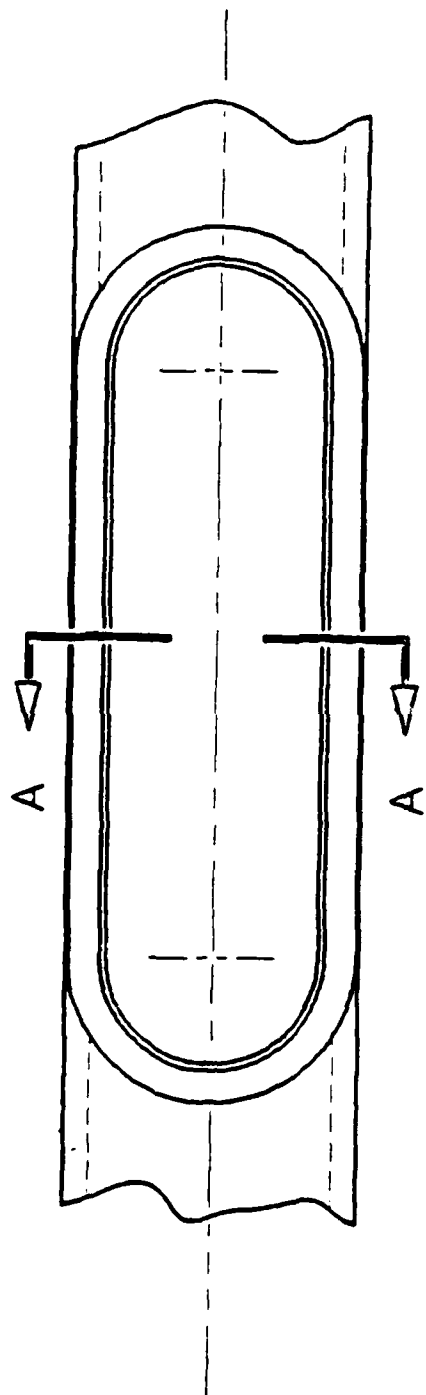
LUG DETAIL



LTHD 114
15 JANUARY 1987
TR

FMC

ACCESS HOLES

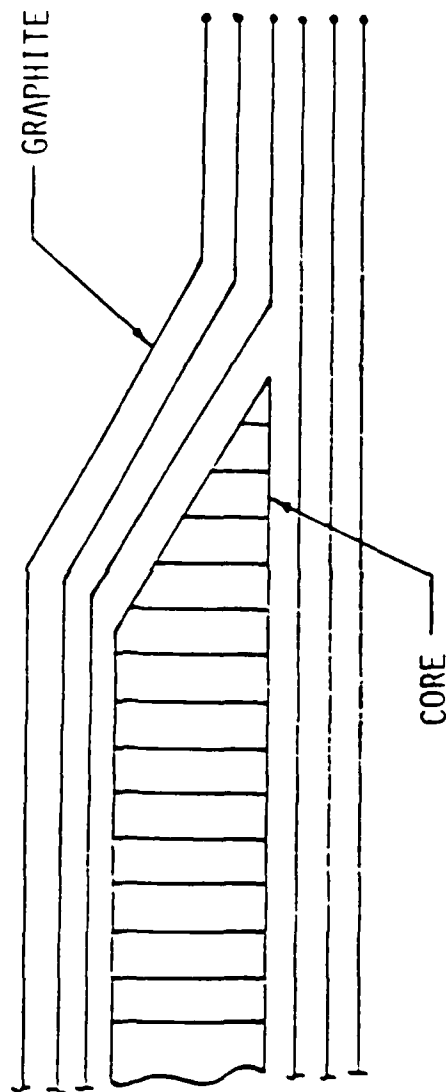


SECTION A-A

LTID 115
15 JANUARY 1987
TR

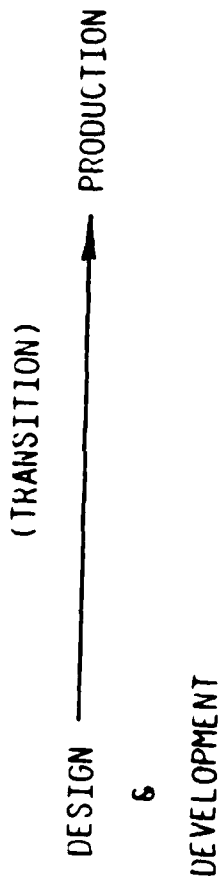
FMC

EDGE DETAIL.



LTND 116
15 JANUARY 1987
TR

FMC



LTHD 117
15 JAN. 1987
FA

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FMC

MANUFACTURING ACTIVITIES TO DATE

- 0 PRODUCIBILITY SUPPORT
- 0 INITIATED PROCESS DEVELOPMENT ACTIVITIES
 - COMPOSITES
 - METAL MATRIX COMPOSITE
 - TITANIUM

LTHD 110
15 JAN. 1987
FA

FMC

MANUFACTURING NEAR TERM TASKS

- 0 DEVELOPE PROCESS PARAMETERS
 - COMPOSITES
 - METAL MATRIX
 - TITANIUM
- 0 PRODUCIBILITY SUPPORT FOR DETAIL DESIGN PHASE
- 0 FINALIZE MAKE/BUY FOR PROTOTYPES
- 0 GENERATE PROCESS INSTRUCTIONS FOR PROTOTYPE FABRICATION

LTHD 119
15 JAN. 1987
FA

FMC

MANUFACTURING PROCESS DEVELOPMENT
ALUMINUM METAL MATRIX COMPONENTS

YOKE

TAP/MILL/BORE
DRILLING
WELD

WAY

DRILLING
WELDING

RECOIL CYLINDER
INTERNAL GRINDING
EXTERNAL GRINDING
TURNING

TRAIL

FABRICATION
WELDING

CLAW

WELDING
DRILLING
EXPLOSIVE WELD

WHEEL BRAKE
WELDING
TURNING
DRILLING
BORING

LTHD 120
15 JAN. 1987
FA

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FMC

MANUFACTURING PROCESS DEVELOPMENT
TITANIUM COMPONENTS
BAND
MUZZLE BRAKE
INTERRUPTED THREAD MACHINING
CRADLE BUSING
TURNING
DRILL/TAP
EXTERNAL GRINDING
GIMBAL
PLATE/PLATE WELD
TURNING
DRILLING/BORING
SLOT MILLING
PLATFORM
WELDING
DRILLING/BORING
SPOT FACING
SPADE
WELDING
CUTTING
DRILLING/BORING
LOADING SYSTEM
WELDING
DRILLING/BORING
BOLTS
EXTERNAL THREADS

LTHD 121
15 JAN. 1987
FA

121

FMC

TEST SCHEDULE

	DEC	JAN	FEB	MAR	APR
1101					
1102					
1103					
1110					
1111					
1120					
1130					
1140					
1150					
1201					

LTHD 122
15 JANUARY 1987
TR

FMC

GRAPHITE/EPOXY QUALIFICATION

TESTING

	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>
	12 19 26 2 9 16 23 30		9 16 23 30
Test Plan Approval	▽		
Material Quality Control Certification Test	▽	▽	
Fabricate Samples		▽	
42-Day Water Soak at 125 F Then 30 Min at 200 F			▽
Set Up Apparatus			▽
Test Samples			▽
Report			▽

LTHD 123
15 JANUARY 1987
TR

123

B/800

19 FEB 87

ARDEC VISIT TO FMC
PHASE II

ACTION PLAN

- o FMC will present a get well plan at ARDEC no later than 4 Mar 87
 - o Address concerns in structures, analysis and man-machine interface
 - o Address schedule problems - How to get back on schedule
- o ARDEC and FMC will intensively manage this program to ensure successful resolution of concerns

ANALYSIS

- o Finite element analysis inadequate on primary structures
- o Buckling limitations of cradle not addressed
- o Critical areas of primary structures not analyzed
- o Fatigue not addressed
- o Damage tolerance not addressed
- o Environmental effects not addressed
- o Ballance of forces not updated

STRUCTURES

- o Material selection inappropriate for primary structures
- o Loading paths and conditions undefined for trail structures undefined
- o Analysis indicates that cradle will degrade after very few cycles
- o Fiber orientation will be difficult to maintain with proposed manufacturing process
- o Thermal stresses not addressed

CERTIFICATION ISSUES

(NAD C 86132-60 ; FAA AC 20-107A)

• STATIC CERTIFICATION

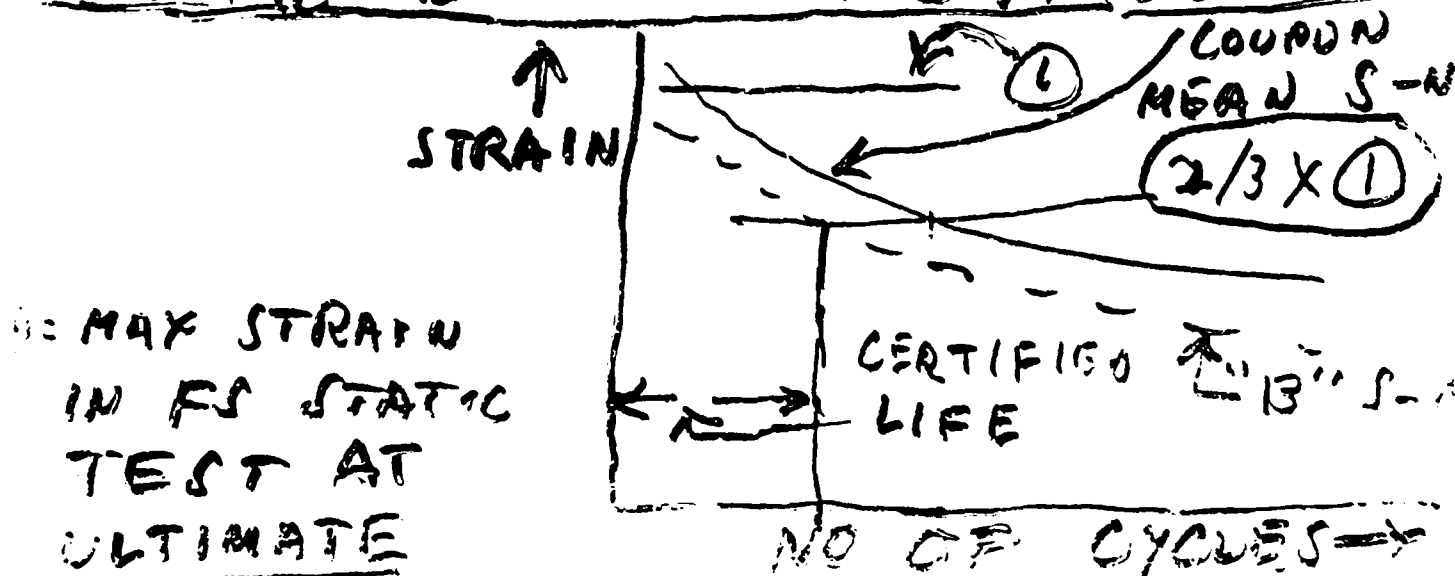
1. FULL SCALE COMPONENT STATIC TEST
(AMBIENT CONDITIONS)

2. REQUIREMENT:

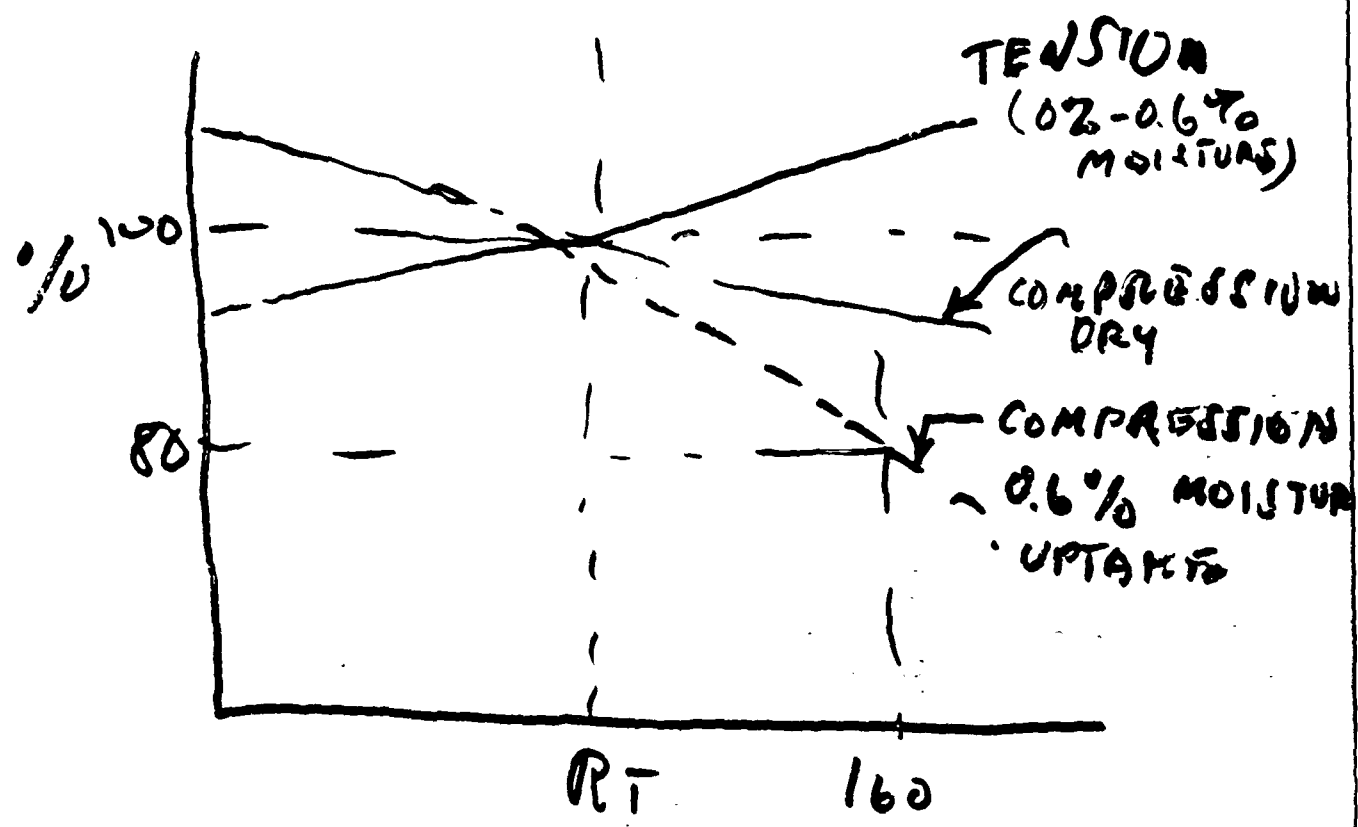
a. STRAINS \leq COUPON ALLOWABLES
FOR WORST CASE ENVIRONMENT

b. MARGIN OF SAFE LOAD OVER
ULTIMATE \geq KNOCK DOWN FACTOR
ON COUPON ALLOWABLES FOR
WORST CASE ENVIRONMENT

• FATIGUE CERTIFICATION



EFFECT OF ENVIRONMENT ON MECH PROPS OF GRAPHITE EPOXY

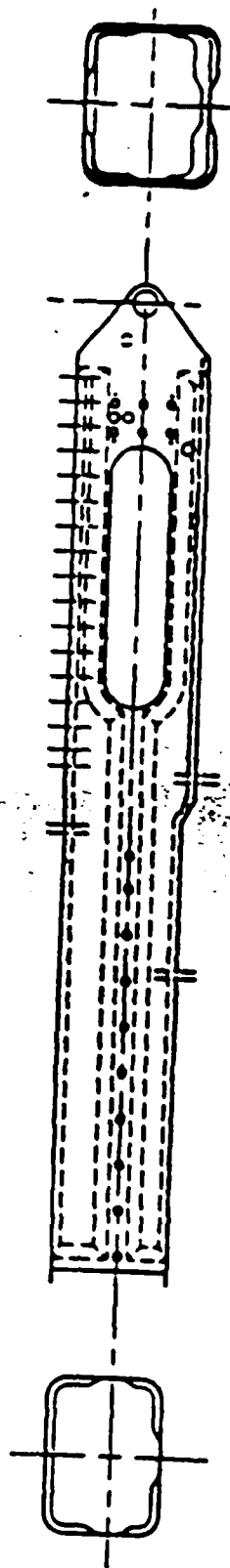
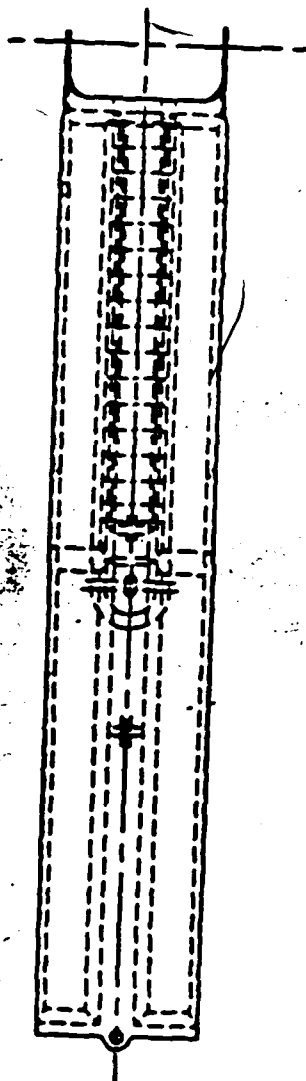


STRUCTURAL ANALYSIS AREA OF CONCERN

- STRESS & DEFLECTION ANALYSIS OF
CRADLE FRONT END
- ATTACHMENT DESIGNS & STRESS ANALYSES:
 - CABLE ATTACHMENTS
 - ELEV. CABLE II
 - TRAIL REAR ATTACH.
 - TRAIL WEB STRUT ATTACH.
 - CRADLE REAR END ATTACH.
- DYNAMIC ANALYSIS
 - CRADLE
 - TRAILS / CABLES
 - OVERALL SYSTEM
 - CRADLE DYNAMIC / STATIC BUCKLING
- COMPOSITE CONSTRUCTION
 - PROVIDE DRAWINGS SHOWING
ALL COMPOSITE COMPONENTS
WITH CONSTRUCTION DETAILS /
WALL THICKNESSES / PRECISE
MATERIAL DESCRIPTIONS

FVIC

CRADLE



LTID 107
15 JANUARY 1987
TR

CRADLE RESULTS

NOTE: ONLY HALF OF STRUCTURE SHOWN

GR - EPOXY AND CORE AREAS

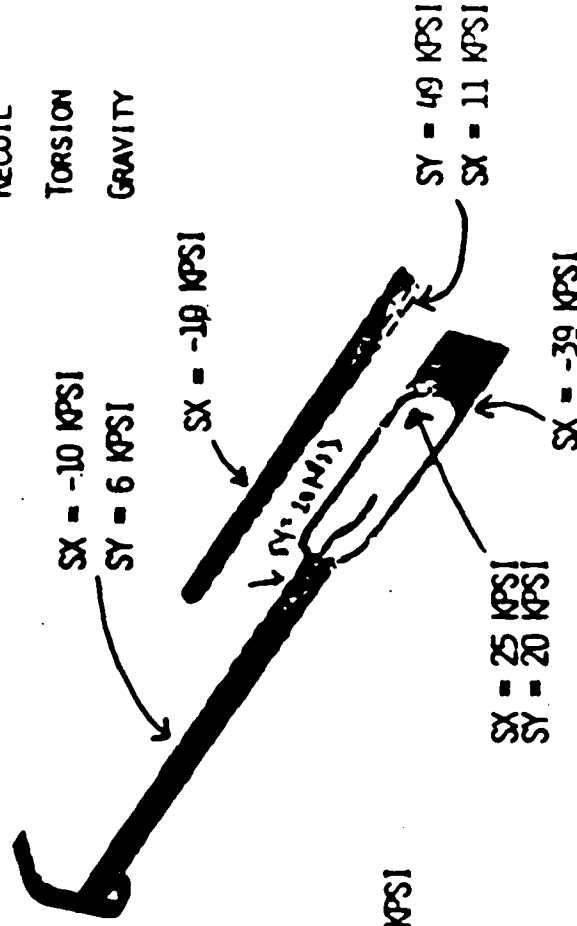
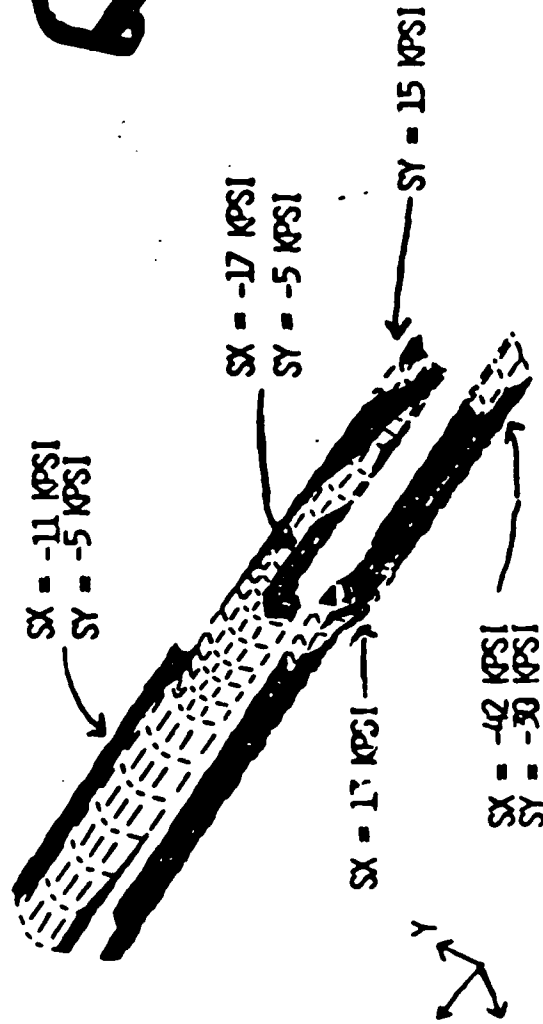
GR - EPOXY ONLY

LOAD: STATIC

RECOIL

TORSION

GRAVITY



MODAL SUMMARY

MODE #	FREQUENCY	DIRECTION	DESCRIPTION
1	2.33	Y	OUTLINE
2	3.11	X	OUTLINE
3	4.34	X	CHILL
4	4.38	Y	CHILL
5	4.38	Y	CHILL
6	4.38	Y	CHILL
7	4.38	Y	CHILL
8	12.0	Z	20 MOVING
9	12.4	X-Z	Torsion Boundary
10	31.3	Y	MOVING

- 0 TORSIONAL DISPLACEMENT = 3.5°
- 0 COMPRESSIONAL DISPLACEMENT = $-.52 \text{ IN.}$
- 0 SMALLER MODEL VALIDATED MODE SHAPES AND GROSS STRESS
- 0 DYNAMIC RESULTS IN PROCESS
- 0 TSAI- μ VALUES BEING CALCULATED

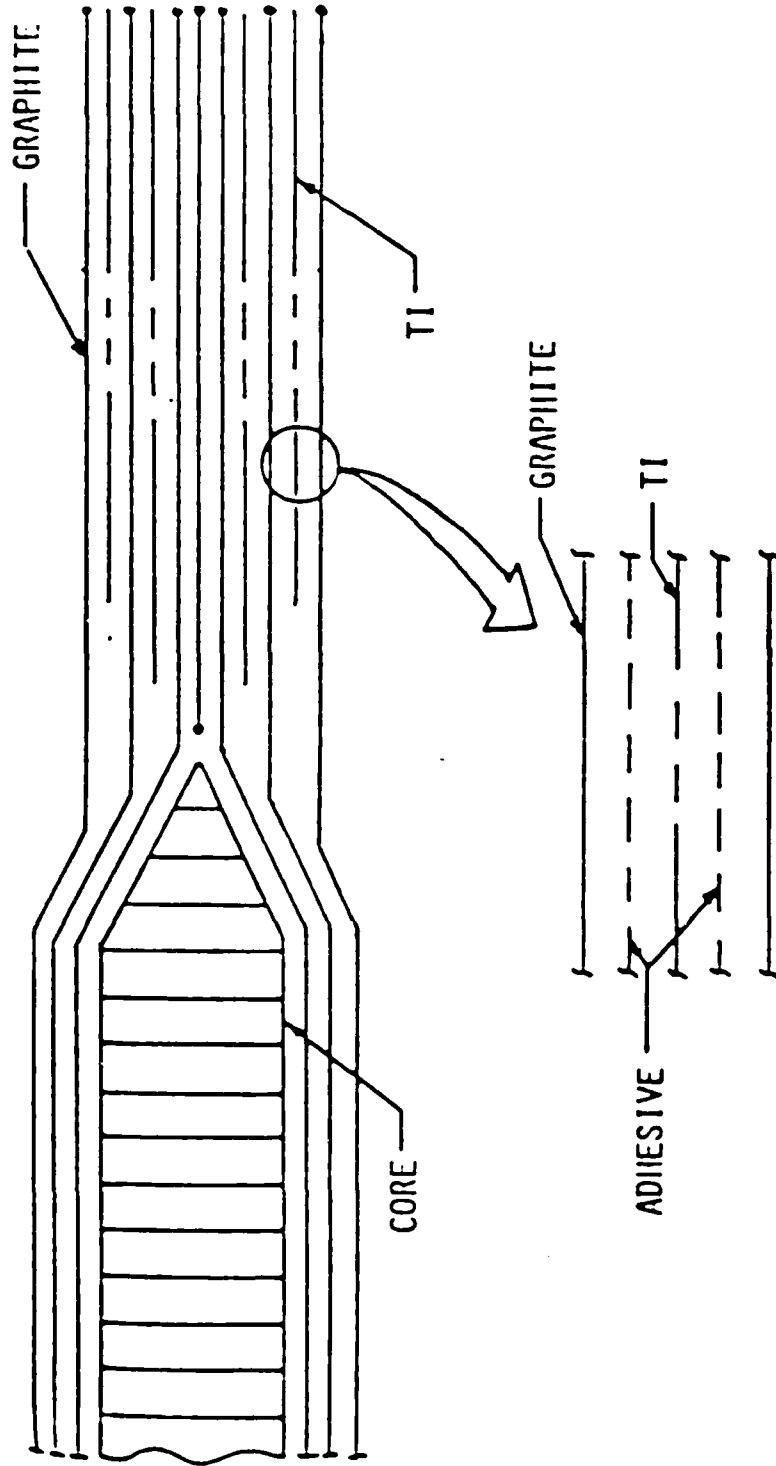
LTHD 84

15 JANUARY 1987

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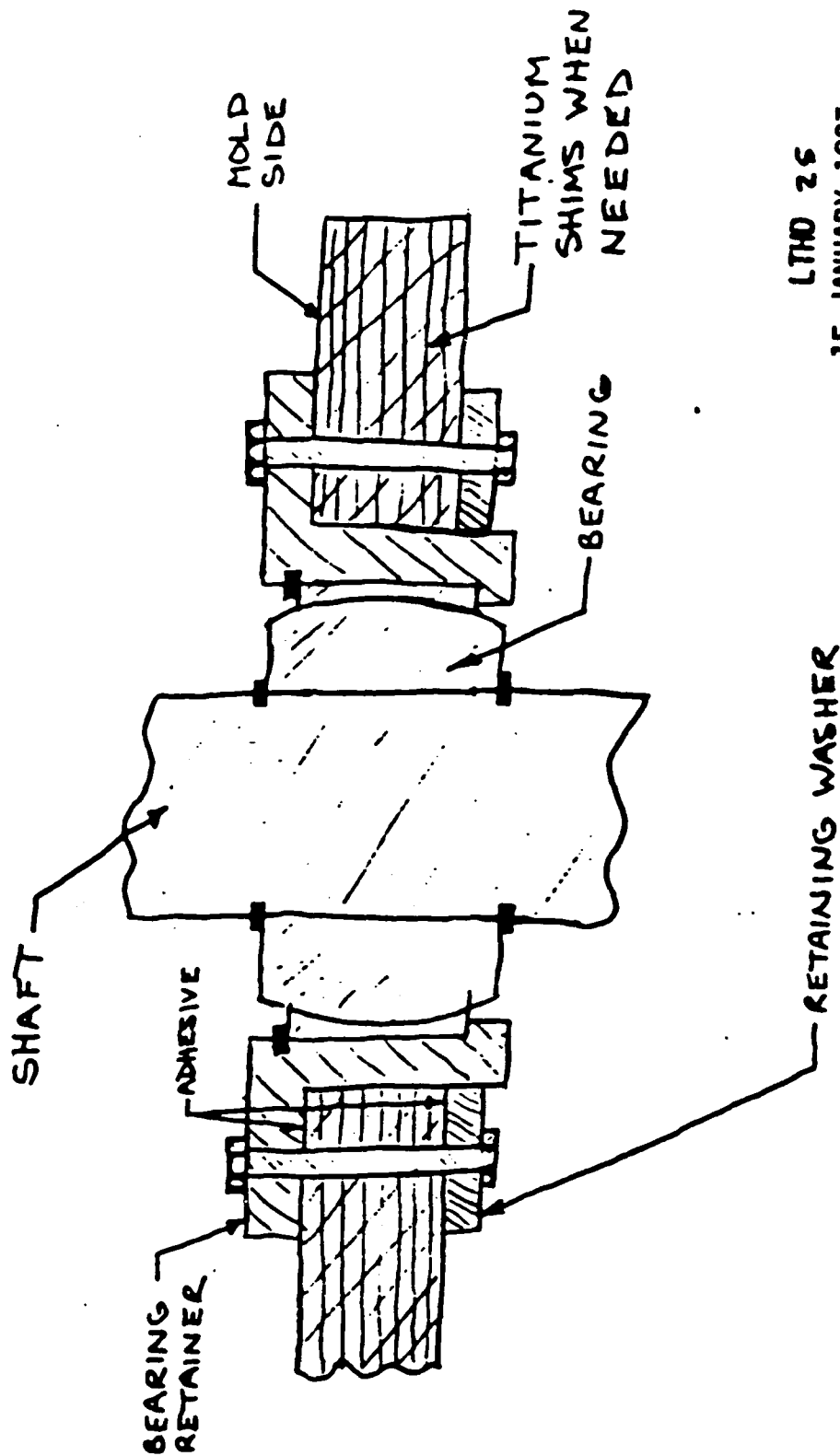
FBI

LUG DETAIL



LTID 114
15 JANUARY 1987
TR

FMC



LTHD 25
15 JANUARY 1987
BA 18

AD-A183 984

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87

4/4

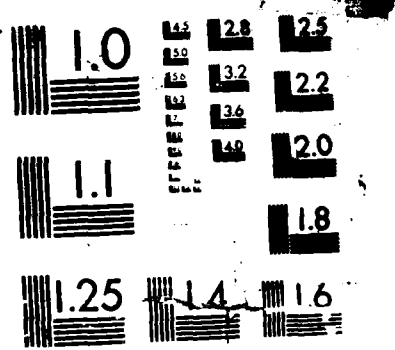
UNCLASSIFIED

FMC-E-3841-VOL-8-PT-2 DAAA21-86-C-8847

F/G 19/6

NL





MAN-MACHINE INTERFACE

- O CONTROL LOCATIONS HAZARDOUS TO OPERATORS
- O LOCATED ON A MOVING PART
- O BREECH OPERATION
- O ECONOMIC CONSTRAINTS
- O PROJECTILE EMPLACEMENT ON LOADING TRAY CAN INJURE OPERATORS HAND

B/900

04 MARCH 87

TECHNICAL PRESENTATION
PHASE II

Bert.

March 5, 1987

FMC Action plan to address Red Team concerns.

1

Introduction:

1 Composite Trail and Cradle

- A. Assessment and Recommendation for composite fabricator
- B. Schedule for composite parts
- C. Structure and analysis concerns.
fatigue, damage tolerances and environmental effects.

2 Other Technical concerns.

- A. Stability analysis update
- B. Long Lead item List
- C. Man machine interface
- D. Plans for remaining composite parts.

3 - Program Status report.

A. TDP status

B. Schedule for remaining tasks

C. ~~Spending Plans - Phase II and III~~

~~D. Proposal for funding cost growth Phase II~~

The listed personnel visited the following composites manufacturers. The primary motive was to source the critical path components for the LTMD project (items are cradle and trail assemblies, subcontract value estimated at \$350,000 to \$500,000). Note that this translates into \$370 to \$525/lbm (including prototype tooling).

	Representing	Paid By	Heath Tecna	Mitco	Ciba-Geigy	Fiber Tech	Morton-Thiokol
Bruce Zierwick.	Adv Tech.....	O'hdX..	...X...
Jim Wallace....	LTMD (Adv Mfg)..	LTMD	..X..	..X..	..X..	..X..	...X...
Dick Lyons.....	Purchasing.....	O'hd	..X..	..X..	..X..	..X..	...X...
Larry Libhardt.	LTMD (Analysis).	LTMD	..X..	..X..	..X..	..X..	...X...
Bart Anderson..	LTMD (Design)...	LTMD	..X..	..X..	..X..	..X..	...X...

The tentatively agreed to schedule for these parts is shown in Exhibit 1. Scale models will be used (preferred by the composite vendors) to minimize the cost and time required to arrive at a mutually agreeable design. Drawings will not go beyond the rudimentary level until a mutually agreeable design is reached (01 Apr).

The characterization matrix for these vendors via group consensus is shown in Exhibit 2. The weighting matrix and results for the cradle are shown in Exhibit 3, while that for the trails are shown in Exhibit 4. Key characteristics are circled.

These matrices will be used to explain our logic relative to selecting composites vendors to ARDEC for the LTMD as well as to justify vendor selection as it relates to competitive bidding requirements.

Additional detail is, of course, available from the people listed above.

Exhibit 2: Basic Characterization Matrix

Characteristic	Wt'ng Factr	Meath Tecna	Hitco	Ciba- Geigy	Fiber Tech	Morton- Thiokol
Ability to supply parts on time.....	...10	...9	...0	...1	...7	...8
Specific Experience Factors						
Similar parts.....
Structural analysis.....32	...8
Heavily loaded joints.....35	...8
High strain rates.....64	...9
Hand lay up.....93	...3
Fiber winding.....48	...9
Weaving.....00	...6
Total.....
Specific Cost and Time Factors						
Prototype cost.....
Potential production cost.....
Struct testing capabilities.....00	...0	...2
Probability of del'y on time.....87	...6	...8
Total.....
General Experience Factors						
Resin systems.....	...4	...75	...9
Core systems.....	...2	...95	...3
Protection against damage.....	...2	...75	...9
Material compatibility.....	...1	...74	...9
Military requirements.....	...1	...74	...9
Total.....	...10	...7448	...78
General Cost and Time Factors						
Travel cost & time from NOD.....	..1.5	...55	...5
Travel cost & time from ARDEC.....	..0.5	...33	...3
Prototype capacity available.....	...2	...84	...8
Prototype tooling expertise.....	...3	...94	...8
Organizational flexibility.....	...3	...95	...7
Total.....	...10	...7944	...70
Summary						
Specific Experience Factors.....
Specific Cost and Time Factors.....
General Experience Factors.....
General Cost and Time Factors.....

Exhibit 3: Characterization Matrix Applied to Cradle

Characteristic	Wt'ng Factr	Heath Tecna	Mitco	Ciba- Geigy	Fiber Tech	Norton- Thiokol
.....
Ability to supply parts on time.....	...10	...9	...0	...1	...7	...8
Specific Experience Factors						
Similar parts.....	...2	...35	...7
Structural analysis.....	...1	...32	...8
Heavily loaded joints.....	...2	...35	...8
High strain rates.....	...2	...64	...9
Hand lay up.....	..1.5	...93	...3
Fiber winding.....	..1.5	...48	...9
Weaving.....	...0	...00	...6
-----	-----	-----	-----	-----	-----	-----
Total.....	...10	...4747	...74
Specific Cost and Time Factors						
Prototype cost.....	...3	...36	...5
Potential production cost.....	...3	...37	...7
Struct testing capabilities.....	...1	...00	...2
Probability of del'y on time.....	...3	...86	...7
-----	-----	-----	-----	-----	-----	-----
Total.....	...10	...4257	...59
General Experience Factors						
Resin systems.....	...4	...75	...9
Core systems.....	...2	...95	...3
Protection against damage.....	...2	...75	...9
Material compatibility.....	...1	...74	...9
Military requirements.....	...1	...74	...9
-----	-----	-----	-----	-----	-----	-----
Total.....	...10	...7448	...78
General Cost and Time Factors						
Travel cost & time from NOD.....	..1.5	...55	...5
Travel cost & time from ARDEC.....	..0.5	...33	...3
Prototype capacity available.....	...2	...84	...8
Prototype tooling expertise.....	...3	...94	...8
Organizational flexibility.....	...3	...95	...7
-----	-----	-----	-----	-----	-----	-----
Total.....	...10	...7944	...70
Summary						
Specific Experience Factors.....	..0.3	...4747	...74
Specific Cost and Time Factors.....	..0.2	...4257	...59
General Experience Factors.....	..0.3	...7448	...78
General Cost and Time Factors.....	..0.2	...7944	...70
-----	-----	-----	-----	-----	-----	-----
Grand Total.....	..1.0	...6149	...71

Exhibit 4: Characterization Matrix Applied to Trails

Characteristic	Wt'ng Factr	Heath Tecna	Mitco	Ciba- Geigy	Fiber Tech	Morton- Thiokol
Ability to supply parts on time.....	...10	...9	...0	...1	...7	...8
Specific Experience Factors						
Similar parts.....	...3	...63	...4
Structural analysis.....	...1	...32	...8
Heavily loaded joints.....	...1	...35	...8
High strain rates.....	...1	...64	...9
Hand lay up.....	...2	...93	...3
Fiber winding.....	...2	...48	...9
Weaving.....	...0	...00	...6
Total.....	...10	...5642	...61
Specific Cost and Time Factors						
Prototype cost.....	...4	...36	...5
Potential production cost.....	...3	...37	...7
Struct testing capabilities.....	...1	...00	...2
Probability of del'y on time.....	...2	...86	...7
Total.....	...10	...3757	...57
General Experience Factors						
Resin systems.....	...4	...75	...9
Core systems.....	...2	...95	...3
Protection against damage.....	...2	...75	...9
Material compatibility.....	...1	...74	...9
Military requirements.....	...1	...74	...9
Total.....	...10	...7448	...78
General Cost and Time Factors						
Travel cost & time from NOD.....	..1.5	...55	...5
Travel cost & time from ARDEC.....	..0.5	...33	...3
Prototype capacity available.....	...2	...84	...8
Prototype tooling expertise.....	...3	...94	...8
Organizational flexibility.....	...3	...95	...7
Total.....	...10	...7944	...70
Summary						
Specific Experience Factors.....	..0.2	...5642	...61
Specific Cost and Time Factors.....	..0.3	...3757	...57
General Experience Factors.....	..0.2	...7448	...78
General Cost and Time Factors.....	..0.3	...7944	...70
Grand Total.....	..1.0	...6148	...66

6

Exhibit 1: Schedule for Cradle and Trails (critical path composite components)

04 Mar	Receive bids from MTI, Heath-Tecna, FiberTech
** 10 Mar	Select and notify composite vendors
10 Mar to 15 May	MOD and composites vendor(s) jointly establish design.
11 Mar	Composite vendor(s) visit MOD to understand application and analysis. FMC and composite vendor(s) to agree upon analytical approach.
17 Mar	Composites vendor to provide design allowables and environmental conditions compatibility for material system recommended. FMC to provide structural loading requirements.
24 Mar	Composite vendor(s) to present program plan to ARDEC.
01 Apr	Formal CPFF contract with not to exceed cap in place.
** 01 Apr	FMC to provide design envelope (define all tooling surfaces)
01 Apr to Sep 15	FMC designer available to composites vendor(s) (onsite).
15 Apr	Composite vendor(s) and FMC to explain process and QC plan to ARDEC
20 Apr	Composites vendor(s) order long lead items
20 Apr	Composites vendor(s) complete tooling design
** 15 May	FMC and composites vendor(s) to agree upon cross-sectional details necessary to meet weight, structural, and mfg requirements. FMC to provide detailed engineering (but not fabrication) drawings.
** 20 May to 01 Aug	Composites vendor(s) fabricate parts. NDI only in suspect or high risk areas.
20 May	Composites vendor(s) to recommend test site(s)
15 Jun	FMC to supply titanium bulkhead
** 03 Aug to 15 Sep	FMC coordinates structural testing. Composites vendor to facilitate "repair" of any structural deficiencies.

JEFF'S PROFILE (12,500 LB-SEC)
 FIRING WT = 9000 LB
 RECOILING MASS = 3870

CONDITION	WT AT EACH TAIL (LBF)	INITIAL SYSTEM CG FM PIVOT (IN)	INITIAL TAIL DEF (IN)	MAX HOP HT (IN)	DEF OF BARREL IN INCHES AT 15MS	PEAK ROD PUN
18.5 round HT SPADE IN GROUND FIRE FM BATTERY	3481	165	1.16	1.18	.003"	75K
SPADE 31.25 round HT AGAINST CURB FIRE FM BATTERY	3276	156	1.09	2.62	.006"	75K
SPADE IN GROUND COOK OFF FM LOAD	3152	150.3	1.05	2.10	.025"	90,127# 82.5K
SPADE AGAINST CURB COOK OFF FM LOAD	2948	140.55	.98	4.12	.046"	DTTTO

~20K AT SHOT EJECTION

SPRIKE
AVG PEAK

Sunk

8

LTHD

LONG LEAD ITEM COSTS
IN DOLLARS

2-4-87
DRR

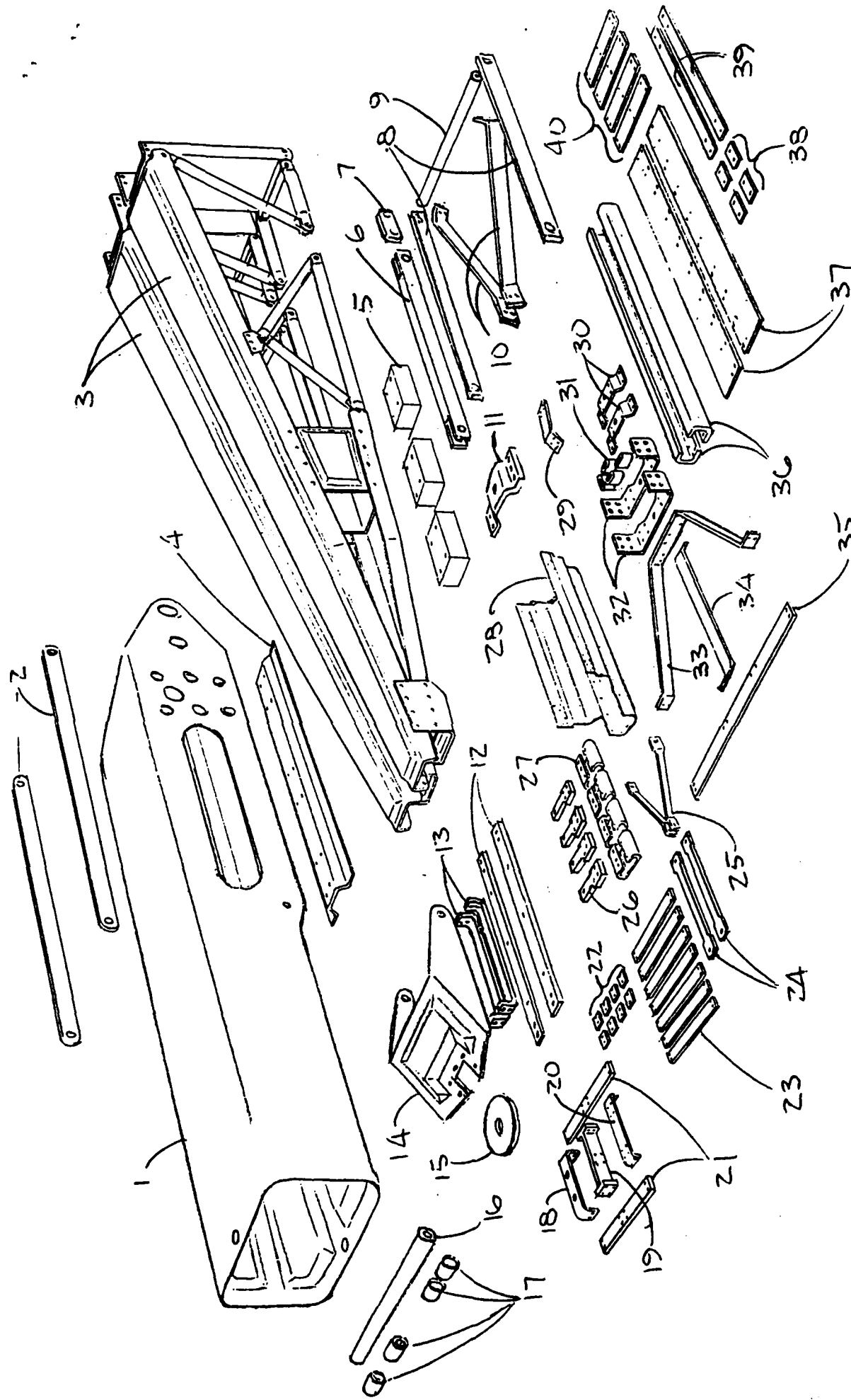
K=1000

ITEM	MAR	APR	MAY	JUNE	JULY	AUG
ALSIK PARTS		20K	60K	13K		
MATLS		93K	10K	5K		
ENGAG		17K	21K	21K	2K	
OUT SERVICES		6K	50K	20K	50K	20K
CASTING-TIG4						
PATTERN	11.5K	6K	5.5K			
ENGAG	5K	5K	5K			
MATLS		6.3K	2K	2.3K	6K	6K
TITANIUM						
MATLS	6K	6K	6K			
FITTINGS						
RODANS	0.5K					.4K
CONTROL VALVES						
MAROTTA		50K	50K	25K	20K	
BOLTING		10K	40K	40K	5K	
TITANIUM HDW		3K	10K			
ACTUATORS						
YORK		5K	2K	2K		
COMPOSITES		25K	50K	75K	75K	
CRADLE		25K	50K	75K	75K	
TRAILS		25K	50K	75K	75K	
MANIFOLDS						
MATL	19.7K	2K	2K	14K		
DIRECT FIRE SCOPE						
ENGAG	7.1K	119.6K	268.5K	275.3K	222K	28.8K
TOTAL	42.7K	235.3K	202K	263K	178K	921.3K

921.3K 28

MAN-MACHINE INTERFACE

- 0 CONTROL LOCATIONS HAZARDOUS TO OPERATORS
 - 0 LOCATED ON A MOVING PART
 - 0 BREECH OPERATION
 - 0 ECONOMIC CONSTRAINTS
- 0 PROJECTILE EMPLACEMENT ON LOADING TRAY CAN INJURE OPERATORS HAND



FLAT & CURVED PANELS
 HEATH TECNA OR GEL OR NOD
 STRUTS & TUBES
 MORTON-THIOLKOL OR CEIBA-GEIGY

AS OF 3-3-87 TOTAL DATA PACKAGE STATUS

233	DRAWINGS <u>DETAILED</u>	55.2 %
170	DRAWINGS <u>IN LAYOUT</u>	40.3 %
19	DRAWINGS <u>IN NOT FIRM-REMAINING</u>	4.5 %
<hr/>		<hr/>
422	TOTAL	100 %

NOT FIRM-REMAINING DRAWINGS ARE IN THE
FOLLOWING AREAS:

- BASIC ISSUE ITEMS - CONTAINER
- NAMEPLATES AND LOCATION
- MISC WEAR PADS, CLAMP PLATES, SHIM PACKS
- GIMBAL VALVE BLOCK
- TRAVEL SUPPORT BAND
- BEAM, EQUIL/GIMBAL
- TRAVERSE ACTUATOR MOUNT
- FRONT OF CRADLE SUPPORT

END

10-87

DTIC